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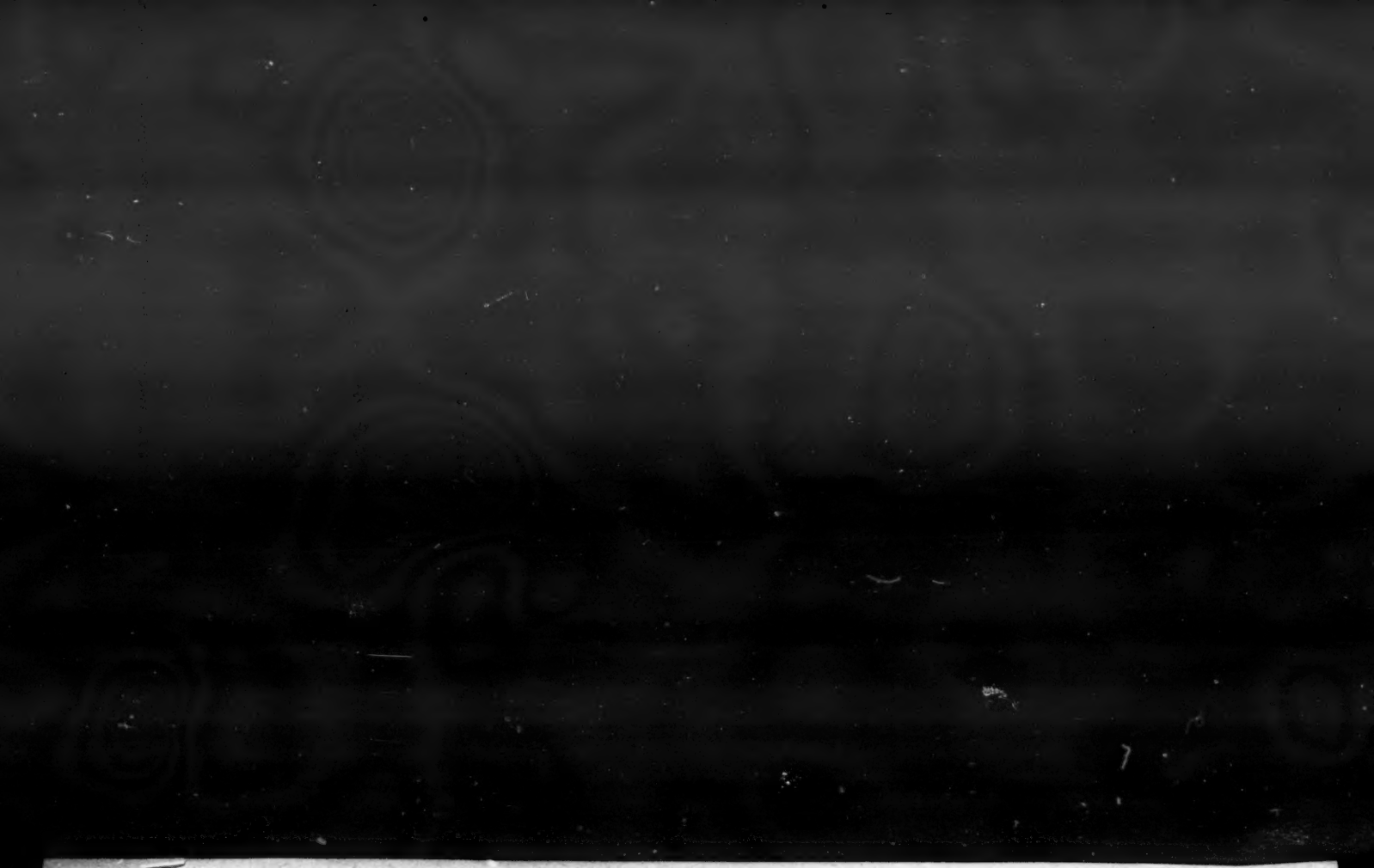


THE

AMERICAN JOURNAL OF SCIENCE

[FOURTH SERIES.]

ART. XLVI.—*Missourite, a new Leucite Rock from the Highwood Mountains of Montana;* by WALTER H. WEED and LOUIS V. PIRSSON.*

THE Highwoods form one of the isolated mountain groups of central Montana which rise like islands from the great treeless plains stretching eastward from the slopes of the Rocky Mountain Cordillera, and forming the great basin of the Missouri River. They consist of a group of extinct, greatly eroded volcanoes, and the elevations which now compose the area are formed chiefly of tuffs, breccias, and lava flows resting on Cretaceous sediments, together with intruded stocks or cores of massive granular rocks which represent the former centers of volcanic activity and from which great numbers of dikes radiate outward in all directions.†

In the preparation of a report on the geology of this mountain group it has been found that the body of granular rock forming the core at one of the denuded volcanic centers is composed of a new rock type whose petrologic character is of exceptional interest. As the type, moreover, proves to be of great importance to systematic petrography, it has been thought best to present a brief account of the rock and its mode of occurrence, a more detailed description and the discussion of its geological and petrographical relations being reserved for the report in preparation.

* By authority of the Director of the U S. Geological Survey. Field geology and collection of material by W. H. W; microscopical petrography by L. V. P.

† A sketch of the geological features of the region, with a geological map, has already been published by the authors. Bull. Geol. Soc. America, vol. vi, p. 389, 1895.

The stock or core is situated at the head of Shonkin Creek, a large stream draining the northern part of the mountains. The headwaters of this stream have cut deeply trenched channels through the mountains and have exposed the granular rock. The region, although mountainous, is almost devoid of timber. Smooth grassy slopes with occasional low rock exposures generally prevail.

Geological occurrence.—The new rock type described forms a stock of granular rock intrusive in Cretaceous shales and in the fragmental volcanic material which overlies them, both being highly altered near the contact with the igneous mass. These enclosing rocks are cut by a multitude of dikes, radiating from the core as a center and forming the most conspicuous feature of the surrounding country.

The igneous rock forming the stock constitutes an irregular mass 2½ miles long and in places half as wide. Where covered by the sedimentary strata, the structure simulates that of a laccolith, but careful study showed that the intrusion is not of this character. The igneous rock was in part intruded between the sedimentary rocks and the volcanic breccias which overlaid them, and in part injected along the bedding planes of the sedimentary strata at the edges of the stock. At the south end of the core a coarse agglomerate of massive rock represents the filling of a vent of a volcanic throat, the material of the blocks and cement varying greatly in granularity but consisting essentially of the same type composing the main body of the core.

Constituting beyond all doubt a geological unit, the rock mass of this volcanic stock varies considerably both in coarseness of grain and in the proportion of its constituent minerals. The specimen selected for description and analysis represented the coarsest grained and freshest variety observed.

The rock seldom forms conspicuous exposures; near the contact it is sometimes weathered into castellated masses and pinnacles, but the usual outcrop is low and hidden by the debris blocks into which the rock ordinarily weathers. Platy parting was observed near the contact, but elsewhere the fracture is massive and determined by shrinkage planes.

Megascopic characters.—Seen in the outcrop, the rock appears dark gray, coarse grained, and resembles many basic massive rocks in appearance. In the specimen it is seen to be coarsely and evenly granular and to be composed of light and dark constituents, the proportion by bulk being about two of the light to three of the dark minerals. The separation by the heavy fluids shows, however, that by weight the white mineral forms only one-fifth to one quarter of the whole. The distinction in color is strongly marked and gives the rock a mottled mosaic-like appearance.

Upon examination the dark constituents may be distinguished as chiefly a greenish black augite in columnar masses and aggregates which are never idiomorphic, together with an occasional speck of a bronzy brown biotite of ill-defined outline or a grain of a deep yellow olivine. Filling the interspaces between these dark minerals in formless masses is a very pale greenish gray substance which is leucite. The average size of crystal grain varies from 2 to 5^{mm}, so that the rock is of quite coarse granular structure, and it resembles most strikingly in fact many coarse-grained gabbros.

Microscopic characters.—The thin section under the microscope shows the minerals present to be *apatite*, *iron ore*, *olivine*, *augite*, *biotite*, *leucite*, and some zeolitic products.

The *apatite* and *iron ore*, which are present rather rarely in moderate-sized grains, show nothing of especial interest beyond that they are found enclosed in the other minerals, and the biotite frequently encloses the iron ore.

The *olivine* is extremely fresh, unaltered in any way, and resembles the olivine of fresh gabbros. It contains great numbers of very fine glass and iron ore enclosures. It never shows any crystal faces, but is in rounded, formless, anhedral grains which are frequently enclosed in biotite and augite.

The *augite* is of a pale green color with a tone of brown; it is very fresh and clear, contains enclosures of ore and specks of biotite and is entirely allotriomorphic, though the orientation of the ore grains is at times zonal, thus indicating crystal planes. It has an excellent cleavage and twinning bands pass through it in places; it does not show any pleochroism.

The *biotite* is strongly pleochroic between a deep umber brown and a pale yellow brown; it is also entirely allotriomorphic though apt to surround the other minerals in bands, especially the olivine and iron ore. It is particularly characteristic in such cases that it then passes from brown into an olivine green variety which has a mottled, somewhat stringy, fibrous appearance. It appears in these cases as if the brown variety had suffered from some magmatic process; it does not seem to be due to any ordinary process of weathering.

Leucite.—The leucite appears also like the other minerals in formless masses filling the interspaces between other minerals. It is perfectly clear and free from all inclusions, except now and then a grain of the ferromagnesian minerals. Between crossed nicols it shows most beautifully the cross-banded twinning structure so characteristic of leucite. It is in general perfectly clear, limpid and fresh, though in some areas, in delicate fringes along cracks and on the borders of grains, a low birefraction shows that processes of zeolitization have commenced. This will be described more in detail later.

As the presence of actual leucite itself has never before been demonstrated, so far as we know, in a granular plutonic rock, it became a matter of importance to prove its identification beyond all doubt.

For this purpose a considerable portion of the rock was crushed, sifted, washed, and treated with the potassium mercuric iodide solution. Immediately all of the ferro-magnesian minerals sank, leaving the white component floating. On then lowering the specific gravity by dilution, nothing except an occasional grain fell until 2·465 was reached, when a very little of the white powder came down. This under the microscope proved to consist of isotropic grains with attached particles of pyroxene and biotite which had evidently increased their specific gravity. This behavior of the rock powder in the heavy solution proves the absence of all feldspars and nephelite, thus confirming the microscopic examination. On now lowering the specific gravity of the liquid to 2·405, the great bulk of the white component came down, leaving a small portion floating. The average specific gravity of this material may be taken as 2·44. Examined under the microscope it was found to be a very pure product, consisting of clear isotropic grains which here and there showed a faint birefraction. An analysis of it (by L. V. Pirsson) gave the following results:

			Molecular ratios.
SiO_2	54·46	·907	·907 = 4·12 = 4·
Al_2O_3	22·24	·216	·220 = 1 = 1
Fe_2O_3	·68	·004	
MgO	trace	----	·213 = ·97 = 1
CaO	·10	·002	
K_2O	18·86	·200	
Na_2O	·70	·011	
H_2O	2·29	----	
	99·33		

The formula is therefore $KAl(SiO_3)_2$ and the mineral is consequently leucite. There appears to be a very slight deficiency of alkalies, and this may be due in part to replacement by water, whose presence is undoubtedly due to processes of zeolitization which are commencing and which may be in part the cause of the faint birefraction noticed above. The small amount of soda shows the leucite to be a very pure potash compound. So far as we know, this is the first analysis of a leucite from other than an Italian locality, with the exception of that given by Steinecke* of the mineral from Choi in Persia.

* Jüngere Eruptivgesteine aus Persien, Inaug. diss., Halle, 1887, p. 12.

Zeolitization and a probable new zeolite.—The small portion of powder which was left floating in the heavy solution after the precipitation of the leucite at 2·405 was found to come down gradually as the specific gravity was lowered. At 2·357 much had already fallen. At 2·30 a small portion was still floating, and this was then thrown down and analyzed, in the hope of learning what the character of the zeolitization mentioned above had been. Examined under the microscope it was found to consist of isotropic grains, presumably analcite, mingled with a substance of low birefraction. The amount of material was less than ·4 gram, and of this one-tenth gram was taken for the determination of water.

The analysis (by L. V. Pirsson) gave the following results:

			Ratios.	A.	B.
SiO_2	50·18	·836	·836	4	3·46
Al_2O_3	25·07	·243	·243	1·16	1
Fe_2O_3	trace	----			
CaO	1·70	·030	·224	1·06	·93
Na_2O	6·53	·105			
K_2O	8·36	·088			
H_2O	9·02	·501	·501	2·39	2·06
Total	100·86				

The substance dissolved readily in acid with separation of gelatinous silica. The ordinary analytical errors are of course somewhat magnified by the small quantities operated upon, but as great care was taken it is not believed they are sufficient to affect the ratios. In the first column under A one-quarter of the silica is taken as unity, under B the alumina is taken as unity. It will be seen that the ratio of the protoxides to the sesquioxide to the water is 1 : 1 : 2, as demanded by the analcite formula, but that there is a deficiency of silica. The microscope having already shown that two substances are present, one of them isotropic and most probably analcite, if we consider the soda present as forming that mineral and deduct sufficient silica, water and alumina to make with it analcite, the remainder reduced to 100 becomes:

	Found.	Ratios.				Calculated.
SiO_2	45·85	·764	·764	3·01	3	44·6
Al_2O_3	26·07	·253	·253	1	1	25·6
CaO	3·12	·056	·218	·86	1	3·4
K_2O	15·35	·162				17·5
H_2O	9·61	·534	·534	2·11	2	8·9
	100·00					100·0

This yields approximately the formula $(K_2Ca)Al_2Si_3O_{10}.2H_2O$, which is exactly that of a natrolite $Na_2Al_2Si_3O_{10}.2H_2O$, in which potash and lime have replaced soda. The ratio of $CaO : K_2O$ is 1 : 2·91 or almost exactly 1 : 3, and the theoretical composition of such a compound ($K_6Ca\ Al_8Si_{12}O_{40}.8H_2O$) is given above in the column to the right, and it can be seen that the agreement with the amounts obtained is moderately close. If, on the other hand, we assume that the potash yielded by the analysis belongs to leucite and consider it the isometric mineral, then the soda and lime would belong to a mesolite-like mineral, but in that case the agreement of the ratios is very poor and the water entirely too high. The material also floated at a specific gravity of 2·30 and was thrown down below this, which should have excluded leucite, if present in the proportion the amount of potash would indicate. It is reasonable to suppose also that the zeolitization of leucite would yield a potassic compound and not a sodium one. Taking into consideration the mathematical chances against the improbability of the above ratios being accidental and the natural chemical possibility of a potash molecule similar to natrolite, it is not unreasonable to infer that we have a potash zeolite of the natrolite type in this rock.

In thin section this zeolite is seen as small feathery particles of low birefraction running in narrow bands around the leucites and along fractures; it evidently attacks the mineral from the outer surfaces. In places where it has grown into considerable areas, the areas, while they extinguish as units, are seen to be composed of a curious grouping of two substances in winding, interlaced, vermicular forms almost exactly like micrographic intergrowths of quartz and feldspar, but excessively fine. Of these two substances one is birefractive, the other isotropic, and from what has already been said it seems probable that they are a mixture of the potash zeolite with analcite.

Occasional separate isotropic grains also occur, which do not show the cross-banded twinning of the leucite, and these are supposed to be also of analcite.

Chemical composition.—A mass analysis of the rock has been made for the U. S. Geological Survey laboratory by Mr. E. B. Hurlburt of the Sheffield Scientific School, which gave the following results (average of two):

	I.	II.	III.	IV.	Ia.
SiO_2	46·06	47·28	46·73	44·35	·767
Al_2O_3	10·01	11·56	10·05	10·20	·097
Fe_2O_3	3·17	3·52	3·53	13·50	·020
FeO	5·61	5·71	8·20		·078
MgO	14·74	13·17	9·68	12·31	·391
CaO	10·55	9 20	13·22	11·47	·188
Na_2O	1·31	2·73	1·81	3·37	·021
K_2O	5·14	2·17	3·76	4·42	·054
H_2O	1·44	2·96	1·24	?	·080
TiO_2	·73	·88	·78	?	·009
P_2O_5	·21	·59	1·51	?	
MnO	trace.	·13	·28	----	
BaO	·32	?	?	?	
SrO	·20	?	?	?	
SO_3	·05	----	none.	----	
Cl	·03	·18	·18	----	
	99·57	100·08	100·97	99·62	
Cl = O	·01	·04	·04		
	99·56	100·04	100·93		

I. Missourite, head of Shonkin Creek, Highwood Mountains, Montana. E. B. Hurlburt, analyst.

II. Leucite absarokite (Hague, this Jour. vol. xxxviii, p. 43, 1889. Iddings, Jour. Geol., vol. iii, p. 938, 1895. J. E. Whitfield, analyst.

III. Shonkinite, Square Butte, Highwood Mountains (Bull. Geol. Soc. Amer., vol. vi, p. 414, 1895). L. V. Pirsson, analyst.

IV. Leucite basalt, Bongsberg by Pelm Eifel (Hussak 77 Bd Sitzb. K. Akad Wiss. Wien I Abt. 1878). E. Hussak, analyst.

Ia. Molecular ratios of No. I.

This analysis brings out strongly the leading characteristics of the rock, its very high lime, iron and magnesia, which have compelled the formation of such quantities of pyroxene and olivine; the predominance of potash over soda, which with the low silica have conditioned the formation of the leucite, and which explains also why no feldspars have formed.

The endeavor to compare this rock chemically with the effusive leucite basalts, of which it forms the plutonic representative, has not been entirely satisfactory owing to the lack of accurate and complete analyses of them. A number of analyses exist but are deficient in important determinations, and in some cases it is clear, from what is stated concerning the mineralogical composition, that the separation of the magnesia and alumina is inaccurate, the magnesia being in part thrown down with the

alumina. This is unfortunately an all too common error in rock analyses. One of the best is shown in the above table in No. IV, and it will be seen that the agreement is good in the essential details. In No. II is given one of the absarokites of Iddings, with which the missourite, from a chemical point of view, seems to be closely related. In No. III is shown the composition of the shonkinite from the same mountain group. With the same amount of silica in each, the lower alkalies of the shonkinite have permitted orthoclase to form as the dominant white mineral, while their higher amount in the missourite has produced leucite in its place. In the shonkinite the excess of the alumina over the alkalies has gone into the augite and biotite, and the same is undoubtedly true in the missourite. Taking into consideration the ratios shown by the analysis, the separations by the heavy liquid and the study of the section, the rock has approximately the following mineralogical composition:

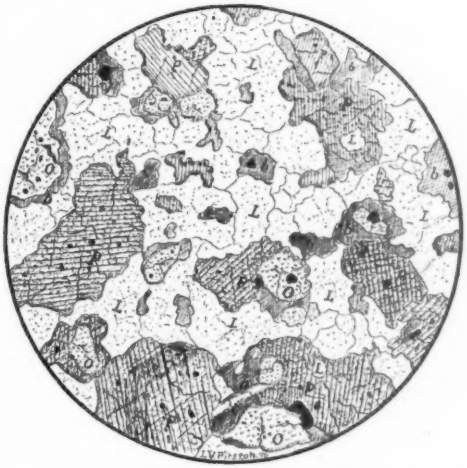
Iron ore	5
Augite	50
Olivine	15
Biotite	6
Leucite	16
Analcite	4
Zeolites	4
	100

Structure.—The structure is purely granitoid, but is not hypidiomorphic since no mineral shows any crystal planes, but all are wholly allotriomorphic. The iron ore, apatite and olivine commenced forming before the other minerals, but are in rounded anhedral grains; the augite and leucite were crystallizing contemporaneously, as shown by the fact that each encloses grains of the other. In plain light the rock section appears precisely like those of many coarse-grained, massive gabbros, and it is not until the nicols are crossed that it is perceived that the colorless areas are not composed of striated plagioclase but of isotropic leucite.

The relations of the minerals are shown in the accompanying figure.

Classification.—It is clear from what has been said in the foregoing that this rock is a new type, and it fills a place which has hitherto been vacant in all systems of rock classification in which either the texture, structure and granularity of rocks or their geological mode of occurrence is taken into account. It is the massive, granular, plutonic representative of the leucite basalts and bears the same relation to them that gabbro bears to

the ordinary plagioclase basalts or granite to rhyolite. It is closely related to theralite, shonkinite, and ijolite, but cannot be classed under any of these types and must therefore be dis-



Micro-drawing of Missourite × 6; P = pyroxene, O = olivine, *b* = biotite L = leucite.

tinguished by a special name of its own. We have therefore called it *missourite* from the Missouri River, the most prominent and best known geographical object in the region where it occurs.

Washington and New Haven, May, 1896.

ART. XLVII.—*The Silveria Formation;* by OSCAR H. HERSHEY, Freeport, Ill.

IN a recent number of the American Geologist,* the writer discussed, under the name of "Kansan Buried Loess," a small series of blue and brown laminated silts, exposed in a ravine one and one-half miles south of the city of Freeport, Stephenson county, Illinois. At the time, this one very limited exposure furnished the only definite information of this formation which had been secured. Subsequent studies, however—carried on chiefly through the examination of well-sections—have shown this formation to be an unusually important one, not only from its bulk, but also from the light which it throws on the relative altitude of northwestern Illinois during the earlier portion of the Kansan epoch. It has, therefore, been thought advisable to again place the subject before the geologic public, and this paper may be considered as a preliminary description and definition of the formation.

The fact is, of course, known to the writer that buried silts, nearly identical in lithologic constitution and stratigraphical position, have been discovered in several counties in northern Illinois, and also in that portion of Iowa which closely adjoins this area. But as there is always more or less uncertainty connected with the correlation of buried silts in different areas when their direct continuity has not been traced, and as this formation appears to be best developed in Stephenson county, Illinois, I will confine my remarks to that section of country exclusively.

The Silveria formation is a thick bed of stratified silt of a nearly uniformly dark bluish-gray color, and which occupies and nearly fills the deep-buried portion of the Pecatonica valley and its tributary valleys in northwestern Illinois. It is penetrated by nearly all the wells in the vicinity of the present streams, and is popularly known as "blue clay." It is, however, not a true clay as it does not contain the necessary percentage of exceedingly fine particles. This statement leads us directly to the manner of discriminating it from blue till or bowlder clay, which is sometimes penetrated by wells in this same district. The blue till is lighter in color, more calcareous and finer-grained, presents no evidences of stratification, and contains irregularly disseminated and comparatively abundant pebbles and small bowlders largely of foreign rock species. The blue silt differs from it chiefly in the following particu-

*Early Pleistocene Deposits of Northern Illinois. Am. Geol., vol. xvii, No. 5, May, 1896.

lars: Besides its usually very dark blue gray or blue brown color, there are bands several feet in thickness which are of a lighter tint. These are encountered in contiguous well-sections at about the same depth, indicating apparently horizontal stratification. Microscopically, the deposit is a very fine-grained sand or silt, with many of the particles angular and sub-angular (one of the distinguishing characteristics of a *loess*). It usually contains a few sparsely disseminated rock fragments of small size, and they have so far, except in the extreme lower portion of the formation, proven to be *exclusively of angular white chert.* Near the base, in the deeper valleys, there are, interstratified with the blue silt, thin strata of fine gravel, composed mostly of the angular chert fragments with a few Canadian pebbles. The blue color dominates this formation so completely that even this gravel is stained with a blue tint, thereby enabling us to readily discriminate it from another gravel formation buried in the valleys, but which is of a bright red and reddish-brown color. Certain thin layers of the blue silt are, also, thickly packed with sharply angular white chert fragments which probably reached their present position through the agency of floating ice. Not only is this great preponderance of angular fragments of white chert, and almost total absence of the ordinary drift pebbles, of the greatest aid in distinguishing the presence of this formation in the material brought up by the sand pump, but it is believed also to indicate that the area in which the deposit occurs had not previously been glaciated. The white chert is of local derivation, being contained abundantly in the residual material over the Galena and Niagara limestones, the terranes chiefly exposed in northwestern Illinois.

At the single surface exposure in this county, so far as at present known (described in the paper already mentioned), the Silveria formation, besides displaying all the characteristics discovered in well-sections, is laminated in the irregular manner commonly known as "ripple marking." The upper two feet are false-bedded, ferruginous, light-brown, fine sand and silt, and appear to represent the shore deposit of the ancient lake in which this formation was laid down. It is here sparingly fossiliferous. There are, uniformly disseminated and apparently largely responsible for the blue color, minute particles of carbon. In addition, also, the fossil flora is represented by very diminutive fragments of black semi-decayed wood. But the only interesting portion of the fossil contents consists of several species of small shells. These occur pretty generally distributed through the exposed portion of the deposit in the proportion of several hundreds to every cubic foot of silt. But in the upper division, described above as representing

apparently a shore or just off-shore deposit, they increase in proportionate numbers. This division of the formation had not been exposed previous to a heavy flood which occurred during this spring, and the fossil contents of the formation had not been professionally studied at the time of the preparation of the previous paper on the subject. Lately, however, several collections from this horizon have been made and submitted to Mr. W. H. Dall, whose report is as follows:

"No. 1 is probably a variety of *Pyramidula striatella* Auth. It is larger, better-developed, and less rugose below than the recent specimens with which I have compared it. No. 2 appears to be *Pupa blandi* Morse, though a young shell mixed with the others may be *Vertigo ovata* Say. No. 3 is *Succinea avara* Say; a fragment of a *Helix*, like *H. tridentata* Say, was intermingled. There is nothing depauperate about the specimens."

The three species undoubtedly present are represented by about the following proportionate numbers of individuals: *S. avara*, 50, *P. blandi*, 5, and *P. striatella*, 2. They are practically a portion of the ancient terrestrial fauna of the neighborhood, and with this fact in mind the significance of their increase in numbers in the apparent shore deposit becomes readily apparent. The number of species is too limited to warrant our drawing very definite conclusions from them as to the nature of the climate of that time. Their rather robust development would seem to negative the idea of a cold climate, but the presence of the ice-sheet in Illinois necessary to the supply of material for the formation of this deposit, undoubtedly introduced a cooler climate than the present. I have previously held to the position that the comparative scarcity of the faunal and floral remains enclosed within this deposit, which was peculiarly favorable for their preservation, may be considered as indicating the relative severity of the climate.

The position of the Silveria formation in the county of Stephenson may be briefly described as follows: Just previous to the opening of the Kansan epoch, the streams of northern Illinois flowed at the bottom of narrow, steep sided cañons, trenched from 300 to 400 feet below the general upland surface. The first important effect of the approach of the advancing Kansan ice-sheet was to depress this area and cause a silting up of the deep valleys. In Stephenson county the cañon valleys were about half filled with fine gravel and blue silt. This has since suffered great erosion and has been buried deeply under later formations. It is now quite frequently penetrated by wells along the valley sides, but at heights which never exceed 20 feet above the present river level at Freeport. Nearer the

center of the valleys it is almost invariably reached at about 20 feet under the present stream level. Being a stiff, clay-like silt, but slowly pervious to water, all wells upon encountering it must go to the bottom, where a supply of water may be obtained from the basal gravel or from fissures in the solid rock below. In thickness it usually varies at present between 40 and 60 feet, but is occasionally penetrated to the depth of 100 feet. Over the abandoned valley of Yellow Creek about 3 miles S.W. of Freeport, there is a low ridge of drift. A well beginning on this ridge was sunk 183 feet without reaching the solid rock at the bottom of the valley. The deposits passed through were first, brown loam, followed by drift, beneath which "blue clay" was reported to have been penetrated to the thickness of 150 feet. This "blue clay" represents the Silveria formation, which fills up the abandoned valley of Yellow Creek to above the present stream level.

The frequency with which the blue silt is encountered at the height of 20 feet above the present stream level, along the sides of the valleys, shows that, were the later formations stripped from the region, they would be found to have rested upon narrow terraces, bounding on either hand trough-shaped valleys about 40 feet in depth. The horizontal banding, the horizontality of the stratification at the exposure near Freeport and other phenomena connected with the formation, have been considered to indicate that the buried terraces represent the nearly level surface of the deposit when completed. In those portions of northwestern Illinois which are outside of the Pecatonica basin, the deposition of the buried blue silt was probably due solely to subsidence of the land, but in Stephenson county we can explain its unusual development only under the supposition that the Pecatonica valley was closed on the east by a glacier, thus raising the water level considerably above that which the mere subsidence of the region would have done. The probable existence of this extra-glacial lake somewhat complicates the subject, but still it is believed that the valleys in the surface of the silt are valleys of erosion. Not only do these valleys show erosion forms, but they are in proportionate size to the present streams, and are never accidentally partially closed by a strong development of the blue silt. Moreover, erosion is clearly indicated in the exposure near Freeport. In short, the evidence is sufficiently strong to warrant my assumption of their origin as valleys of erosion. Therefore, I shall consider the formation to have originally extended over the central portions of the valleys to practically the same height which it now attains on their sides.

If the importance of the formation be judged by its bulk it will be seen to compare favorably with all the others of the

district. It underlaid one-seventh of the county with an average original thickness of 100 feet. This spread out over the entire county would make a uniform layer of 14+ feet. For the purpose of comparison I will introduce a table in which all the other Quaternary formations of the county have been treated in the same manner.

	Thickness if spread over entire county.
1. Silveria formation	14+ feet.
2. Lake Pecatonica formation	1 foot.
3. Till	4 feet.
4. Stratified drift gravel	2 feet.
5. Angular limestone gravel (drift)	1 foot.
6. Florencia formation	6 inches.
7. Valley *loess*	2 feet.
8. Upland *loess*	7 feet.
9. Modern alluvium	10+ inches.

Superficial deposits of Stephenson County, Ill. Total 32 feet, 4 inches.

Its mass is thus seen to be twice as great as the drift series proper (Nos. 3, 4 and 5) and about one and one-half times as great as the combined mass of the Iowan *loess* series of the region (Nos. 6, 7 and 8.)

The determination of the exact age of the Silveria formation depends on several factors, the precise value of which cannot at present be positively demonstrated. The first is the positive identification of the drift sheet which overlies this formation with that which is exposed in Kansas, and therefore known as the Kansan drift sheet. For reasons which it is hardly necessary to mention here, the oldest drift sheet of northwestern Illinois, southwestern Wisconsin and northeastern Iowa, has been considered as Kansan in age. Moreover, it is supposed to represent the culminating stage or time of maximum advance of the great Kansan ice-sheet. As this correlation is probably correct, I shall assume that the drift sheet of Stephenson County, Illinois, is Kansan in age. Now this drift-sheet rests upon the Silveria formation. Therefore, the age of the latter is not later than the Kansan epoch. Following the usual custom of correlating all formations which are inter-glacial in position, with the inter-glacial epochs, I should pronounce this deposit as a pre-glacial formation. But its evident derivation from material formed during glacial action and (presumably at least) the known position of the glacial front during its deposition, connect it with some stage of glaciation. Therefore, it is neither properly pre-glacial nor inter-glacial in age.

The second factor which creates a difficulty in placing this formation in the geologic time scale, is the exact significance of the eroded valleys in the surface of the blue silt. The drift sheet in the deeper valleys has been mostly removed by subsequent erosion (Aftonian mainly). But locally we find the drift in situations which indicate that the erosion of the valleys in the blue silt was accomplished mainly before the completion of the Kansan epoch. The question remains, however, as to whether this erosion was sub-aerial or glacial in nature. In the exposure near Freeport it is settled in favor of the former hypothesis, for here we find an erosion unconformity with a slightly developed soil and remains of vegetation at its surface, overlain by another extra-glacial lake deposit which itself preceded the arrival of the ice in that vicinity. Strong presumptive evidence that the erosion of all the valleys in the surface of the blue silt was mainly sub-aerial and antedated the arrival at Freeport of the ice-sheet, is furnished by the regularity of the valleys, their nearly uniform depth, and the absence from the till west of Freeport of any large amount of material which could have been derived from this formation. Therefore, we can say that if these valleys are truly valleys of erosion as they appear to be, their excavation was accomplished mainly by sub-aerial agencies, and antedated the glaciation of the region.

It has been assumed, as before stated, that the unusual development and relatively great height which the Silveria formation attains in Stephenson County, was due to obstruction of the valley by the advancing ice-sheet. The sub-aerial erosion within the limits of the former lake area, above partially demonstrated, requires the disappearance of the ice from the lower portion of the valley to give free drainage through the ancient Rock-Illinois valley, then occupied by the ancestor of the present Rock river. The relative importance of this fluctuation in the border portions of the ice-sheet depends largely on the length of the erosion interval above indicated. While the amount of material removed from the immediate vicinity of the streams during this post-Silveria erosion interval was apparently greater than the erosion which has been accomplished in the same position since the Iowan loess series was deposited, I do not think that any very long period was required. Although the completion of the work within 500 years would have converted the ancient Pecatonica river into a stream of "liquid mud," the somewhat increased precipitation of the glacial period, and otherwise more favorable conditions of erosion, may have enabled its accomplishment.*

*The length of time required to deposit the Silveria formation in Stephenson County can only of course be conjectured. If we assume the annual amount of sediment deposited to have had a thickness of one inch, and the average original

The post-Silveria erosion interval has no epochal value, as it was too short, there is no evidence of a marked change of climate, and the ice-sheet probably lay close to the Rock-Illinois valley during the entire time. I should divide the Kansan epoch into a number of sub-epochs or stages of which the time of deposition of the Silveria formation would constitute one stage, the post-Silveria erosion interval another, and the time of glaciation of northwestern Illinois still another. Therefore, the Silveria formation in Stephenson County, Illinois, may be chronologically correlated with an early stage of the Kansan epoch.

The post-Silveria stage of erosion has some bearing on the question of the relative altitude of the region at that time. All the deposits in the valleys of Stephenson County, under the drift sheet and its associated Lake Pecatonica clays, except the Red Gravel before referred to, appear to be genetically connected so that they may be considered as one formation, made up of gravel, sand, and mainly of blue silt—the Silveria formation. Just previous to the beginning of deposition of this formation, the streams flowed from 100 to 200 feet lower than at present. Therefore, the land stood relatively higher. During the post-Silveria stage of sub-aerial erosion, when free drainage was again restored in the Pecatonica basin, the streams flowed about 20 feet under the present water level or over 100 feet above the pre-Silveria stream level. The comparatively great width of the post-Silveria valleys indicates that the interval of erosion was sufficiently prolonged to enable the streams to cut to at least a local base level. Therefore, the land stood relatively lower at the close than it did at the beginning of the Silveria sub-epoch. In other words, the early stages of the Kansan epoch were characterized by a slow subsidence of the land which had returned nearly to its present relative altitude before the maximum extension of the ice-sheet.

The name which I have proposed for the formation discussed in this paper, is derived from that portion of Stephenson county, where it is, so far as at present known, best developed, and in which its only surface outcrop in the Pecatonica basin, occurs. If the deposit in this county should be correlated with some formation already discriminated and specifically designated in other districts, the name of the latter would, of course, have precedence, but the term *Silveria* would still be of some value as a local denomination of the conditions peculiar to the Pecatonica basin, namely as *Lake Silveria*.

Freeport, Ill., July 13, 1896.

thickness of the formation to have been 100 feet, 1,200 years would be required. This estimate probably falls rather below than above the actual time.

Art. XLVIII.—*On the Viscosity of Mixtures of Liquids;* by C. E. Linebarger.

I. *Historical. Object of Investigation.*

The earliest investigations of note on the viscosity or internal friction of solutions were carried out by Girard* and Poiseuille.† "The isolated discovery of M. Poiseuille, that diluted alcohol has a point of maximum retardation, coinciding with the degree of dilution at which the greatest condensation of the mixed liquids occurs," induced Graham‡ to investigate mixtures of other liquids with water as regards their rate of transpiration, as this appeared to him "to depend upon chemical composition, and to afford an indication of it." He made a number of determinations of the internal friction of aqueous solutions of nitric, sulphuric, acetic, butyric, valerianic, formic, and hydrochloric acids, as well as of ethyl alcohol and acetone, finding that usually a maximum of the property in question was observable. "It is remarkable," he writes, "that hydrated liquid compounds appear in general to show only one decided transpiration maximum, as with the 1-hydrate in sulphuric acid, the 2-hydrate in acetic acid, the 3-hydrate in nitric acid, the 6-hydrate in alcohol, and the 12-hydrate in hydrochloric acid."

Wijkander§ determined the viscosity of mixtures of acetic acid and water, aniline and benzene, ether and chloroform, ether and carbon bisulphide, ether and alcohol, and benzene and alcohol at temperatures between 0° and 60°. His results for the mixtures of water and acetic acid corroborated those by Graham for the same mixtures as regards the occurrence of a maximum of the property in question; the position of this maximum, however, varied with the temperature at which the determinations were carried out, a relation of any definiteness between chemical constitution and viscosity seeming not to exist. Mixtures of such of the liquids employed by Wijkander as were composed of normal molecules were found not to exhibit a maximum of the property in question; generally

* Mouvement des fluides dans les tubes capillaires, Mémoires de l'Institut, 1813, 1814, 1815 and 1816.

† Recherches experimentales sur le mouvement des liquides dans les tubes de très petits diamètres, Annales de Chimie et de Physique, III, vii, p. 50, and xxi, p. 76, 1848; also in Pogg. Ann., lviii, 424, 1843.

‡ On the Capillary Transpiration of Liquids in Relation to Chemical Composition, Chemical and Physical Researches, p. 601; and Philosophical Transactions, 1861, pp. 373–386.

§ Ueber die Reibung der Flüssigkeiten, Lunds. Physiog. Sälsk Jubelskrift, 1878; Wied. Beiblätter, iii, 8, 1879. Only the reference in the "Beiblätter" has been accessible to me.

they had a less degree of fluidity than that calculable by the rule of mixtures, and, in the case of the mixtures of ether with chloroform and carbon bisulphide, points of inflection were present in the curves representing the phenomena.

Pagliani and Battelli* made some determinations at 0° and 10° of the internal friction of mixtures of methyl, propyl, and ethyl alcohols with water. They discovered that these mixtures all presented a maximum in viscosity, but that "La ricchezza procentica alla quale corrisponde il massimo di attrito diminuisce col crescere della temperatura, per cui si ha ragione di credere che ad una data temperatura non si abbia pui questo massimo, ma che il coefficiente di attrito delle mescolanze alcooliche vada continuamente crescendo col crescere della proponzione di alcool in esse contenuto."

As a continuation of the work of these Italian physicists may be considered the investigations of J. Traube,† who determined the viscosities of a number of aqueous solutions of several of the organic acids and alcohols.

S. Arrhenius‡ also has measured the fluidity of some organic liquids dissolved in water; his solutions were dilute, containing 10 per cent or less of the dissolved liquid; he observed that usually the viscosity of water is increased by the addition of small proportions of non-electrolytic liquids, but, in a foot note, states that a little acetone, ethyl ether, or methyl alcohol, when added to ethyl alcohol, lowers the degree of viscosity.

An inspection of the determinations of the viscosity of liquids recorded in the papers just mentioned brings to light the fact that all mixtures, which have a maximum of internal friction, contain at least one liquid which is known to be composed of associated molecules; also, that such mixtures as do not present this maximum are made up of normal liquids. It seems legitimate to infer, then, that there is an intimate relationship between the occurrence of a maximum of viscosity in liquid mixtures and the molecular polymerization of the liquids composing them; indeed, it may be said that it is probable that the maximum will be found only in such mixtures as contain associated liquids. Another circumstance which increases the probability of this statement is the fact that the higher the temperature, the less pronounced the maximum, and also, as is well known, the less the degree of molecular complexity. The curves given in Traube's paper are instructive in this respect; they are drawn with concentrations of the axis

* Sull'attrite interno nei liquidi, Annali del R. Istituto Tecnico Germano Sommeiller in Torino. XIII. Anno, 1884–1885.

† Ueber die innere Reibungsconstante und die specifische Zähigkeit organischen Flüssigkeiten und ihrer wässerigen Lösungen, Ber. deutschen chem. Gesell., xix, 871–892, 1886.

‡ Zeitschr. f. phys. Chem., i, 284, 1887.

of abscissas and viscosities on the axis of ordinates for mixtures of water with some of the alcohols of the fatty series, and include the data communicated by Pagliani and Battelli. An inspection of them shows that the most considerable maximum of viscosity is present at the lowest temperature, and that, as the temperature rises, the maximum becomes less and less pronounced. The determinations were not made at temperatures above 60°, but even at this temperature the maximum has in most cases nearly disappeared. But it is known that at 60° the association of the molecules of water and the lower alcohols is still not inconsiderable, so that it is perhaps permissible to assume that at higher temperatures the maximum of viscosity may disappear entirely.

The curves also show that the position of the maximum with respect to the axis of abscissas varies in a regular way, so that it is not allowable to conclude that there is any definite relation between the maximum of viscosity and chemical composition, that is, the interpretation of these data in favor of the hypothesis that the maximum marks the existence of a "hydrate" is untrustworthy.

Now, the only data we possess on the internal friction of mixtures of normal liquids are to be found in Wijkander's paper (loc. cit.) and these are not very numerous or accessible. The object of this paper is the determination of this physical constant for a number of mixtures of normal liquids.

II. *Method of Determination of Viscosity.*

The apparatus used in the determinations of the internal frictions of the liquids and their mixtures was that devised by Ostwald.* Two such instruments were used, one emptying itself of pure water at 25°·0 in 105·6 seconds, the other in 203·5 seconds. One or the other was taken so as to make the time of transpiration at least more than 100 seconds. The time was taken by means of a chronometer to within a few tenths of a second. Never less than three and generally from five to ten determinations were made for each mixture, and their average set down as the true time of transpiration. The apparatus was kept in all determinations at the temperature of 25°·0 by immersing it in several quarts of water of that temperature contained in a large jar of clear glass. As the coefficient of internal friction varies considerably with the temperature, great care was taken to keep the temperature uniform, and it is believed that during an experiment it did not vary more than $\pm 0°{\cdot}02$. The thermometer used was graduated in tenths of degrees and permitted the estimation of a fiftieth of

* Lehrbuch der allgemeinen Chemie, i, 550, 1889.

a degree; it had been shortly before tested by the "Physikalische Reichsanstalt," and had been found to be without appreciable error in the neighborhood of 25°·0.

In order to convert the relative coefficients of viscosity, obtained directly from the experimental data furnished by the apparatus, into coefficients of viscosity expressed in dynes per square centimeter, the former were multiplied by the factor 0·00895; this number being the average of the results obtained for water at 25°·0 by Poiseuille, Sprung, Slatte, and Thorpe and Rodger.*

III. *Experimental Results.*

In the following tables are recorded the experimental results obtained. In the first two columns are given the percentage composition, in the second two the molecular percentage composition, of the mixtures of liquids investigated. These mixtures were prepared by weighing out to less than a milligram the liquids in tared flasks or bottles fitted with the best corks. The fifth column contains the specific gravities at 25°·0 referred to water at the same temperature. In the sixth column are placed the viscosities of the mixtures as calculated from those of their component liquids by the rule of mixtures, while in the seventh are set the viscosities as actually determined. The eighth column finally shows the differences between the calculated and observed viscosities; a plus sign indicates that the calculated viscosity is greater than that determined; a minus sign, the contrary.

TABLE I.

Viscosity of Mixtures of Benzene (a. II) and Ethyl Ether (b.)

Temperature —25°·0

Percentage composition.		Molecular percentage composition.		Specific gravity.	Calculated viscosity.	Observed viscosity.	Diff.
C_6H_6	$C_4H_{10}O$	C_6H_6	$C_4H_{10}O$				
0·000	100·000	0·000	100·000	0·70942		0·00230	
28·576	71·424	27·502	72·498	0·75369	0·00335	0·00282	+0·00052
56·924	43·076	55·627	44·373	0·79972	0·00440	0·00362	+0·00078
75·691	24·309	74·709	25·291	0·83179	0·00509	0·00438	+0·00071
100·000	0·000	100·000	0·000	0·08390		0·00599	

(*a. II.*) About five pounds of "chemically pure" benzene were treated repeatedly with sulphuric acid to remove last traces of thiophene, and fractionally crystallized many times. It was then distilled over some scraps of sodium, the whole of it boiling at 80°·12 (corr.) under a pressure of 757·3^{mm} of mer-

* See Thorpe and Rodger "On the Relations between the Viscosity (Internal Friction) of Liquids and Their Chemical Nature" (Bakerian Lecture), Phil. Trans., 449, 1894.

cury. The distillate was collected in three portions of somewhat over a pound each, and their melting points found to be 5°·39 (corr.), 5°·40 (corr.), and 5°·42 (corr.) respectively.

(*b.*) Five pounds of ether were washed about twenty times with small portions of water, dried over fused calcium chloride, allowed to stand over mercury for a few days, and finally distilled over sodium. Almost the total quantity distilled within 0°·1. The portion which had boiled almost constant was again distilled, this time over phosphoric anhydride, and the distillate collected in two portions, whose specific gravities at 25°·0 referred to water of the same temperature were found to be 0·70940 and 0·70942 respectively.

TABLE II.

Viscosity of Mixtures of Benzene (a. I) and Toluene (c. I.)

Temperature —25°·0

Percentage composition.		Molecular percentage composition.		Specific gravity.	Calculated viscosity.	Observed viscosity.	Diff.
C_6H_6	C_7H_8	C_6H_6	C_7H_8				
0·000	100·000	0·000	100·000	0·86288		0·00541	
10·991	89·009	12·719	87·281	0·86434	0·00547	0·00555	−0·00008
30·588	69·412	34·229	65·771	0·86635	0·00558	0·00558	0·00000
66·576	33·424	70·240	29·760	0·87143	0·00579	0·00579	0·00000
91·556	8·444	92·750	7·250	0·87528	0·00594	0·00594	0·00000
100·000	0·000	100·000	0·000	0·87661		0·00599	

(*a. I.*) About three pounds of benzene were treated with sulphuric acid, and then subjected to fractional crystallization until a little more than a pound was obtained melting at 5°·3 (uncorr.). Most of this, when distilled over sodium, boiled at 80°·1 (uncorr.) under a pressure of 756^{mm} of mercury.

(*c. I.*) Of the quantity of toluene taken for purification (about two pounds) more than four-fifths distilled at 109°·8 to 110°·1 (uncorr.). After a couple of distillations over a little sodium, more than a pound was obtained boiling almost constantly at 110°·1 (uncorr.) under a pressure of 758^{mm} of mercury.

TABLE III.

Viscosity of Mixtures of Benzene (a. I) and Carbon Bisulphide (d).

Temperature —25°·0

Percentage composition.		Molecular percentage composition.		Specific gravity.	Calculated viscosity.	Observed viscosity.	Diff.
C_6H_6	CS_2	C_6H_6	CS_2				
0·000	100·000	0·000	100·000	1·25958		0·00358	
8·872	91·127	8·675	91·325	1·20897	0·00379	0·00376	+0·00003
34·858	65·142	34·270	65·730	1·09314	0·00456	0·00446	+0·00010
75·886	24·114	75·409	24·591	0·94176	0·00541	0·00544	−0·00003
100·000	0·000	100·000	0·000	0·87661		0·00599	

(*d.*) The carbon bisulphide was purified by distillation over dehydrated copper sulphate and mercury, when it was found to have a constant boiling point.

TABLE IV.

Viscosity of Mixtures of Benzene (a. I) and Carbon Tetrachloride (e).
Temperature 25°·0

Percentage composition.		Molecular percentage composition.		Specific gravity.	Calculated viscosity.	Observed viscosity.	Diff.
C_6H_6	CCl_4	C_6H_6	CCl_4				
0·000	100·000	0·000	100·000	1·58828		0·00883	
13·727	86·273	23·860	76·140	1·42900	0·00843	0·00808	+0·00035
40·780	59·220	57·551	42·449	1·19309	0·00766	0·00706	+0·00060
58·600	41·400	73·605	26·395	1·07615	0·00715	0·00660	+0·00055
100·000	0·000	100·000	0·000	0·87661		0·00599	

(*e.*) The carbon tetrachloride had been fractionally distilled over phosphoric anhydride after first being treated with strong sulphuric acid; it boiled at 76°·7 (uncorr.) under a pressure of 754^{mm} of mercury.

TABLE V.

Viscosity of Mixtures of Benzene (a. I) and Acetic Ether (f. I.)
Temperature —25°·0

Percentage composition.		Molecular percentage composition.		Specific gravity.	Calculated viscosity.	Observed viscosity.	Diff.
C_6H_6	$C_4H_8O_2$	C_6H_6	$C_4H_8O_2$				
0·000	100·000	0·000	100·000	0·89663		0·00434	
15·594	84·406	17·250	82·750	0·89311	0·00459	0·00442	+0·00017
51·404	48·596	54·411	45·589	0·8·506	0·00519	0·00487	+0·00032
80·803	19·197	82·605	17·395	0·87982	0·00567	0·00551	+0·00016
100·000	0·000	100·000	0·000	0·87661		0·00599	

(*f. I.*) A kilogram of *c. p.* ethyl acetate was fractionally distilled until about a third of it was found to boil within a few tenths of a degree.

TABLE VI.

Viscosity of Mixtures of Benzene (a. I) and Nitrobenzene (g).
Temperature —25°·0

Percentage composition.		Molecular percentage composition.		Specific gravity.	Calculated attrition.	Observed attrition.	Diff.
C_6H_6	$C_6H_5NO_2$	C_6H_6	$C_6H_5NO_2$				
0·000	100·000	0·000	100·000	1·20200		0·01834	
14·394	85·606	20·956	79·044	1·14200	0·01656	0·01417	+0·00239
37·610	62·390	48·735	51·265	1·05620	0·01369	0·01017	+0·00372
80·653	19·947	86·355	13·645	0·92764	0·00845	0·00681	+0·00164
100·000	0·000	100·000	0·000	0·87661		0·00599	

(*g.*) Commercial nitrobenzene was repeatedly crystallized in fractions until an almost colorless product was obtained, which, when solidified, showed the same temperature during the remelting, viz: 3°·6 (uncorr.)

TABLE VII.

Viscosity of Mixtures of Benzene (a. I.) and Chloroform (h).

Temperature —25°·0

Percentage composition.		Molecular percentage composition.		Specific gravity.	Calculated viscosity.	Observed viscosity.	Diff.
C_6H_6	$CHCl_3$	C_6H_6	$CHCl_3$				
0·000	100·000	0·000	100·000	1·48069		0·00540	
6·967	93·033	10·290	89·710	1·41165	0·00544	0·00546	—0·00002
23·010	76 990	31·411	68·589	1·27568	0·00554	0·00557	—0·00003
72·780	27·220	80·370	19 630	0·98485	0 00582	0·00581	+0·00001
85·831	14·169	90 289	9·711	0·92965	0·00590	0·00587	+0·00003
100·000	0·000	100·000	0·000	0·87661		0·00599	

(*h.*) The chloroform had been fractionated to constant boiling point, and was finally distilled over phosphoric anhydride; its boiling point was 61°·3 (uncorr.) under a pressure of 759^{mm} of mercury.

TABLE VIII.

Viscosity of Mixtures of Toluene (c. II.) and Acetic Ether (f. II.)

Temperature —25°·0

Percentage composition.		Molecular percentage composition.		Specific gravity.	Calculated viscosity.	Observed viscosity.	Diff.
C_7H_8	$C_4H_8O_2$	C_7H_8	$C_4H_8O_2$				
0·000	100 000	0·000	100·000	0·89156		0·00462	
15·708	84·292	15·129	84·871	0·88588	0·00474	0·00466	+0·00008
45·301	54·699	44 202	55·798	0 87529	0·00497	0 00481	+0·00016
71·255	28·745	70·335	29·665	0·86636	0·00517	0·00509	+0·00008
100·000	0·000	100·000	0·000	0·85680		0·00539	

TABLE IX.

Viscosity of Mixtures of Toluene (c. II.) and Ethyl Benzoate (i. I.).

Temperature —25°·0

Percentage composition.		Molecular percentage composition.		Specific gravity.	Calculated viscosity.	Observed viscosity.	Diff.
C_7H_8	$C_9H_{10}O_2$	C_7H_8	$C_9H_{10}O_2$				
0·000	100·000	0·000	100·009	1·04843		0·01954	
15 282	84;718	22·726	77 274	1·01458	0·01737	0·01495	+0·00242
47·322	52·678	59·450	40·550	0·94937	0 01284	0·00939	+0·00345
76·170	23·830	83 918	16 082	0·89667	0·00876	0·00679	+0·00197
100·000	0·000	100 000	0·000	0·85680		0·00539	

(*i.*) Ethyl benzoate was prepared by the action of hydrochloric acid on a mixture of benzoic acid and absolute alcohol. It was repeatedly rectified, and the fraction boiling at 210°·3–210°·8 employed in the determinations.

TABLE X.

Viscosity of Mixtures of Toluene (c. I) and Carbon Bisulphide (d).

Temperature —25°·0

Percentage composition.		Molecular percentage composition.		Specific gravity.	Calculated viscosity.	Observed viscosity.	Diff.
C_7H_8	CS_2	C_7H_8	CS_2				
0·000	100·000	0·000	100·000	1·25958		0·00358	
7·269	92·731	6·082	93·918	1·21783	0·00377	0·00370	+0·00007
39 992	62·008	33·605	66·395	1·06759	0·00427	0·00417	+0·00010
63·242	36·758	58·699	41·301	0·97217	0·00473	0·00469	
100·000	0·000	100·000	0·000	0·86288		0 00541	

TABLE XI.

Viscosity of Mixtures of Toluene (c. II.) and Turpentine (k).

Temperature —25°·0

Percentage composition.		Molecular percentage composition.		Specific gravity.	Calculated viscosity.	Observed viscosity.	Diff.
C_7H_8	$C_{10}H_{16}$	C_7H_8	$C_{10}H_{16}$				
0·000	100·000	0·000	100·000	0·85970		0·01343	
6·791	93·209	9·724	90·276	0·85948	0·01275	0·01192	+0·00083
20·654	79·346	27·464	72·536	0·85838	0·01177	0·00978	+0 00199
53 701	46·299	63·162	36 838	0·85682	0·00911	0·00701	+0·00200
75·091	24·909	89·884	20·116	0·85654	0·00739	0·00607	+0·00131
100·000	0·000	100·000	0·000	0·85680		0·00539	

(*k.*) The sample of turpentine used was kindly furnished me by Prof. J. H. Long of the North Western University, who had had it prepared in his laboratory from pure spruce gum. It had been rectified over sodium and boiled at 156°·5–157°·0 (uncorr.) under a pressure of 745^{mm} of mercury.

TABLE XII.

Viscosity of Mixtures of Ether (m. b) and Carbon Bisulphide (d).

Temperature —25°·0

Percentage composition.		Molecular percentage composition.		Specific gravity.	Calculated viscosity.	Observed viscosity.	Diff.
$C_4H_{10}O$	CS_2	$C_4H_{10}O$	CS_2				
0·000	100·000	0·000	100 000	1·25958		0·00358	
13·100	86·900	13·407	86·593	1·14280	0·00341	0 00338	+0 00003
34·367	65·633	34·969	65·031	0·99180	0·00313	0·00306	+0·00007
62·759	37 241	63·380	36·620	0·84689	0 00277	0·00269	+0·00008
100·000	0·000	100·000	0·000	0·70942		0·00230	

TABLE XIII.

Viscosity of Mixtures of Acetic Ether (f. II) and Ethyl Iodide (n).

Temperature —25°·0

Percentage composition.		Molecular percentage composition.		Specific gravity.	Calculated viscosity.	Observed viscosity.	Diff.
$C_4H_8O_2$	C_2H_5I	$C_4H_8O_2$	C_2H_5I				
0·000	100·000	0·000	100·000	1·93015		0·00577	
21·799	78·201	33·073	66·927	1·52760	0·00552	0·00408	+0·00144
67·427	32·573	78·585	21·415	1·07553	0·00499	0·00462	+0·00037
100·000	0·000	100·000	0·000	0·89156		0·00462	

n. The ethyl iodide was made by the action of iodine and red phosphorus on absolute alcohol; by a couple of distillations, a constant boiling product was obtained, which when again distilled gave two fractions having specific gravities at 25°·0 referred to water at the same temperature, 1·93012 and 1·93015 respectively.

TABLE XIV.

Viscosity of Mixtures of Acetic Ether (f. I) and Nitrobenzene (g).
Temperature —25°·0

Percentage composition.		Molecular percentage composition.		Specific gravity.	Calculated viscosity.	Observed viscosity.	Diff.
$C_6H_5NO_2$	$C_4H_8O_2$	$C_6H_5NO_2$	$C_4H_8O_2$				
0·000	100 000	0·000	100 000	0·89663		0·00434	
22·896	77·104	17·530	82 470	0·95669	0·00755	0·00582	+0·00173
56·100	43·900	47·770	52·230	1·05318	0·01219	0·00889	+0·00350
75·530	24·470	68 870	31·130	1·11618	0·01491	0·01204	+0·00287
100·000	0 000	100·000	0.000	1·20200		0·01834	

TABLE XV.

Viscosity of Mixtures of Carbon Tetrachloride (e) and Chloroform (h).
Temperature —25°·0

Percentage composition.		Molecular percentage composition.		Specific gravity.	Calculated viscosity.	Observed viscosity.	Diff.
CCl_4	$CHCl_3$	CCl_4	$CHCl_3$				
0·000	100·000	0·000	100 000	1·48069		0·00540	
19 269	80·731	15·663	84·337	1·49872	0·00610	0·00569	+0·00041
57·277	42·723	50 989	49·011	1·53772	0·00736	0 00659	+0 00077
81·172	18 828	76·985	23·015	1·56489	0·00818	0·00761	+0·00057
100·000	0·000	100·000	0·000	1·58828		0·00883	

TABLE XVI.

Viscosity of Mixtures of Acetic Ether (f. II) and Carbon Bisulphide (d).
Temperature —25°·0

Percentage composition.		Molecular percentage composition.		Specific gravity	Calculated viscosity.	Observed viscosity.	Diff.
$C_4H_{10}O$	CS_2	$C_4H_{10}O$	CS_2				
0·000	100 000	0·000	100.000	1'25958		0·00358	
16·359	83 641	14·451	85·549	1·16956	0 00375	0·00367	+0·00008
39·246	60·754	35·811	64·189	1·06877	0·00398	0·00389	+0·00009
66·413	33·587	63·069	36·931	0·97681	0 00427	0 00416	+0 00011
100·000	0·000	100·000	0 000	0·89156		0 00462	

(*c. II.*) Five pounds of toluene were fractionally distilled over sodium a half dozen times or so until the larger portion boiled almost at a constant temperature. Three fractions of nearly a pound each were then made, boiling: *a* at 109°·90–109°·94; *b* at 109°·94–110°·00; and *c* at 110°·00–110°·03 under a pressure of 757·7^{mm} of mercury. Their specific gravities at 25°·0 referred to water at 25°·0 were: *a*, 0·85678; *b*, 0·85681 and *c*, 0·85680.

(*f. II.*) Five pounds of commercial acetic ether were dried over fused calcium chloride for a few days; and after filtration from this salt were made to stand over phosphoric anhydride for some time. The ether was then distilled, the distillate being collected in two portions, one of which boiled at 71°·0–71°·3 (uncorr.), the other at 71°·3–71°·4 (uncorr.) Each of these distillates was again distilled over phosphoric anhydride, and both were found to boil at identical temperatures. The specific gravity of one sample at 25°·0 referred to water at the same temperature was determined to be 0·89155; that of the other under similar conditions, 0·89157.

IV. *Discussion of Results.*

The data in the preceding section are seen to be in corroboration of Wijkander's (loc. cit.) results; in no instance does a maximum of viscosity appear. The observed viscosities are all less than those calculated by the rule of mixtures, except in certain mixtures of benzene and chloroform (Table VII) and of benzene and carbon bisulphide (Table III); in these mixtures, however, the differences are less than those detectible by the apparatus, so that they cannot be really counted as exceptional.

With mixtures of certain liquids, as of benzene and toluene (Table II), benzene and carbon bisulphide (Table III), benzene and chloroform (Table VII), toluene and carbon bisulphide (Table X, ether and carbon bisulphide (Table XII) and acetic ether and carbon bisulphide (Table XVI) the differences are so slight that they may be due principally to experimental errors, and, consequently, these liquids may be said to preserve their viscosities without appreciable change in mixture. In other mixtures, on the contrary, considerable differences between the theoretical and found values of the viscosities present themselves, the greatest differences occurring when about equal proportions of the liquids are mixed.

The greater the differences between the viscosities of the pure liquids, the greater is found to be the differences between the calculated and observed values of the viscosities of their mixtures. This is easily seen in the mixtures of benzene, whose viscosity is 0·00599, and nitrobenzene, whose viscosity is 0·01834, differences amounting to 0·00372 being found (Table VI); also, in mixtures of toluene (viscosity = 0·01954), where the differences, found and calculated, are as large as 0·00345.

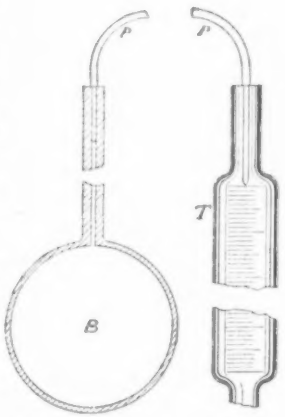
Yet, even when the viscosities of the pure liquids are nearly the same, the differences between the theoretical and observed values of the viscosities of their mixtures is not inconsiderable; thus the mixtures of acetic ether (viscosity = 0·00577) and ethyl iodide (viscosity = 0·00462) there are differences of as much as 0·00144.

Art. XLIX.—*Volume Measurement of an Air Thermometer Bulb;* by Walter G. Cady.

In all constant volume air thermometry where high temperatures are involved, it is frequently necessary to determine the volume of the glass bulb used; such a bulb softens at a low red heat sufficiently to have its volume considerably altered by any difference between the atmospheric pressure and that within the bulb. Thus it is important to know at the end of an experiment to what extent, if any, the volume of the bulb may have changed, as any such change must be taken into account in calculating the temperature.

The usual method of volumetry by weighing with water is long and arduous, involving as it does the taking apart of the apparatus. Below is given a simple and sufficiently accurate method of calculating the volume at any time without disconnecting the bulb. In addition to the usual apparatus it is only necessary that the manometer tube in which the air is confined be graduated for 9 or 10^{cm} from the top, so that the volume of air in the tube may be computed.

In the figure, B is the bulb, PP a capillary connecting tube, T the graduated manometer tube, the graduated portion of which is about 1^{cm} in diameter, connected in the customary manner by flexible rubber tubing with a reservoir. The scale in question is shown at T and is graduated in 0·1^{cms} beginning with the fiducial mark.



Assuming the whole apparatus to be at constant temperature during the operation, the required volume V is easily found as

$$V=\frac{P_2v_2-P_1v_1}{P_1-P_2}$$

when v_2 and v_1 are volume excesses measured by means of the scale on T, corresponding to pressures P_2 and P_1 respectively.

It will be observed that V is not the volume of the bulb alone. Still, since the bulb is the only variable factor, the above formula indicates what change it may undergo.

The following is an example of a number of observations leading to the volume of a glass bulb used; in each case the

first reading is combined with the third, the second with the fourth, in finding the values of $P_2 v_2 - P_1 v_1$ and $P_1 - P_2$.

Reduced atmospheric pressure = 74·76cm.

P (cm.)	v (c.c.)	V (c.c.)
75·17	0·16	239.0
74·63	1·80	241·1
73·79	4·47	
73·27	6·20	

The method is equally serviceable when a long capillary of irregular and appreciable volume joins the bulb with the manometer, a condition sometimes unavoidable in practice: the volume of the capillary may then be separately found by temporarily plugging up its detached end.

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Art. L.—*The Effect of Residual Viscosity on Thermal Expansion;* by Howard D. Day.

In the course of certain laboratory experiments, I observed a condition of molecular instability in vulcanized rubber, due to residual viscosity, which seems to be of sufficient interest to deserve publication.

As the detection of this quality in rubber was made possible by the excellent performance of the apparatus which I employed, a brief description of it will here be given, use being made of the accompanying figure 1.

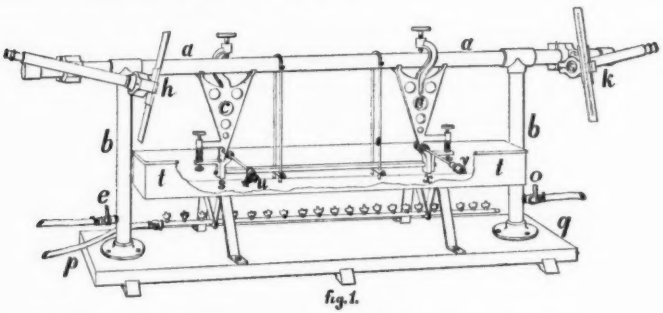


fig. 1.

The apparatus is essentially the well known German apparatus for noting the expansion of solids through ranges of temperature, but it will be seen to embody several novel features,

which, while they are attained by comparatively simple means, yet add greatly to the value of the results obtained by its use; notably, the way in which a base of constant length for a reasonable length of time is secured, and, also, the construction of the parts which support the movable levers, so as to accommodate the use of the apparatus to bars of any length.

A bar of the solid substance whose expansion is to be observed is submerged in the bath, *tt*, which is supported by standards above a solid wooden base, *pq*. The temperature of the bath is raised by means of a multiple gas-jet suspended beneath it.

The ends of the bar actuate contact levers of a convenient pattern, *s* and *x*, which are free to move about horizontal axes. Two rods, projecting from these levers in the line of their axes, support the adjustable mirrors, *u* and *v*. The angular motion of the levers, which measures the expansion of the bar, is determined in the usual way by means of these mirrors and the two telescopes, *h* and *k*, with their attached scales. Any lost motion of the levers is prevented by spiral springs, which, having their ends attached respectively to the fixed parts of the apparatus supporting the levers and to arms on the levers themselves, keep them pressed firmly against the ends of the bar. Thumb-screws serve to regulate the tension of the springs.

In observing expansions, the work is much facilitated, if, instead of having both levers movable, one lever, with its mirror, is maintained in a fixed position by its spring, while all of the motion is exhibited by the other. In this case, the fixity of the non-movable mirror is assured by means of its corresponding telescope.*

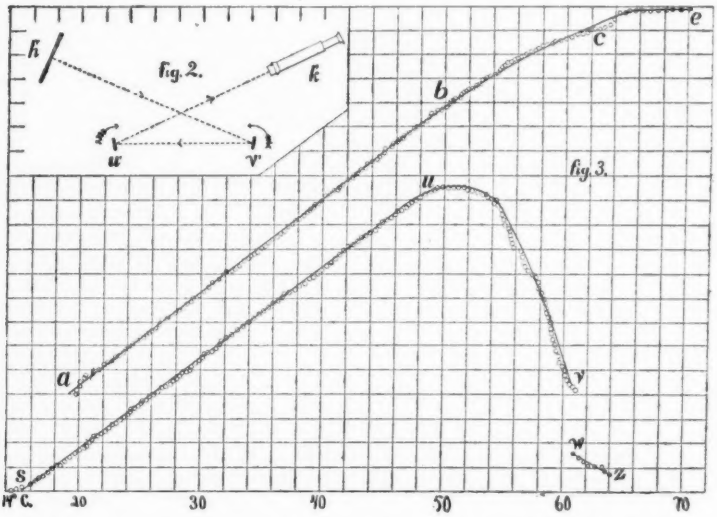
Another arrangement of the optical parts of the apparatus is shown in fig. 2. The telescope *h* is removed and a scale, *h'*, fixed in its place. Both of the mirrors have a possible rotation in the direction of the arrows. The reflected scale-image reaches the eye at the telescope, *k'*, over the path indicated by the dotted lines and arrow heads. Since the successive deflections of the scale-image by the two mirrors are of the same sign, the deflection observed at the telescope will correctly measure the sum of all possible motions of the levers due to either expansion or contraction of the bar. It is clear that the lengths of the contact levers will have to be proportional to the corresponding scale distances, that of the stationary mirror, *u'*, being the longer.

A base of constant length is secured by the following simple means: A bar of $1\frac{1}{2}''$ galvanized iron pipe, *aa*, is supported in a horizontal position directly above the bath upon uprights, *bb*,

* I am aware that similar observations with two telescopes were made on a certain occasion by Prof. W. Hallock.

of the same material, which are connected with it by "T" joints at a short distance from its ends.

These uprights are screwed into circular cast-iron plates, which are rigidly fastened to the wooden base, *pq*. Stop-cocks are inserted in the sides of the uprights near their lower ends, at *e* and *o*. By means of caps on the projecting ends of the bar, *aa*, and plugs in the lower ends of the uprights, *bb*, the framework of piping is made water-tight, and, by connecting one of the cocks, *e*, *o*, with a source and the other with a sink, a continuous flow of water throughout the length of the bar, *aa*, is obtained.



If the temperature of the water passing through the bar remains constant, the bar will not be sensibly affected by the currents of heated air rising from the jets beneath the bath, and the length of any portion of the bar will remain constant. A public main is a convenient source, and, for a reasonable time, will supply a flow of water at a nearly constant temperature.

The projecting ends of the bar, *aa*, serve as convenient supports for the telescopes, *h* and *k*, which are fastened thereto in an adjustable manner, so as to allow them to be focussed upon their respective mirrors, *v* and *u*.

The solid whose expansion is to be observed is suspended in the bath from the bar, *aa*, by light bent rods, while the levers, *s*, *x*, are supported below the same bar, in their proper positions at the ends of the solid, by brackets, *c*, *c*, cast in brass. These

brackets may be clamped in any position along the bar, *aa*, by means of thumb-screws and projecting jaws, and their form is such that they successfully resist the slight force tending to separate their lower extremities.

Since the portion of the bar *aa*, between the brackets is constant in length, owing to the stream of water passing through, it is readily seen that a base of constant length is provided, and that, too, in a simple and effective manner.

Moreover, by means of the movable brackets, the apparatus may be accommodated to solids varying widely in their coefficients of expansion. Thus, the apparatus permitted the testing of a standard meter rod for temperature corrections, while, in the experiments with hard rubber, which are referred to above, a piece of this substance but 15^{cm} in length, which was sufficient to give conveniently large scale-deflections, was used, and the apparatus was readily adjusted to this length of rod.

The data obtained with metal rods are of no special interest, except as they point out the degree of accuracy of the results obtained with the apparatus; at the same time the action of the apparatus is well enough shown in the results obtained with the hard rubber rod, which are exhibited as expansion curves in the accompanying diagram, fig. 3.

A piece of hard rubber tube was examined by means of this apparatus, to determine the range of temperature through which it would maintain a uniform rate of expansion, with results as shown by the curve, *suv–wz*. The rubber maintained a nearly uniform rate up to 50°, when an apparent rapid contraction took place until 61° was reached. At this point the bath was allowed to cool off several degrees and then was raised to 64°, giving the short, detached portion of the curve, *wz*. Evidently, the apparent contraction went on during the cooling and reheating of the bath below 61°. This fact gives a clue to the real cause of the apparent contraction; that it was no real contraction due to a rise in temperature, such as is shown by rubber under certain well-known conditions, but a viscous readjustment of the molecules, after being released by the heat of the bath from a condition of stress due to the previous treatment of the rubber,—probably, in its manufacture.

A subsequent test of the same piece of rubber gave further evidence of this condition of residual viscosity, as is shown by the curve, *abce*. The rubber, as before, maintained a uniform rate up to 50°. From this point up to 64°, a gradual diminution of the rate is observed. At 64°, the highest temperature to which the rubber was previously subjected, a rapid decline is noted.

These results clearly show that the rubber is molecularly stable at a given temperature, if it has long been exposed to

that temperature. When this temperature is reached the residual viscosity again manifests itself, and the rubber undergoes further gradual deformation, which vanishes in its turn.

Thus, the hard rubber tube was evidently stretched at the relatively high temperature of manufacture. The stress was locked up in the tube and maintained at ordinary temperatures. Between 50° and 64°, however, this was not so, and a viscous flow took place, resulting in a shortening of the tube, as shown by the diagram.

The second measurement of the expansion shows that, during the previous exposure to the temperature 50° . . . 64°, excess of strain was nearly wiped out. When the temperature 64° was again reached, however, the viscous yielding reappeared.

Phenomena in tempered steel analogous to this in rubber have been observed in great detail by Barus and Strouhal,* and they have made use of their observations in the production of steel magnets of remarkably stable qualities. They found that steel possessed residual viscosity, which manifested itself as an irregular change of the magnetization in permanent magnets when exposed to relatively high temperatures. By boiling their magnets in water for many hours, they found that they could remove such residual viscosity and render them viscously stable below 100°. This treatment is applied successively both to remove excess of mechanical strain and of magnetization.

A practical result of a knowledge of this quality would be to secure rubber of a stable molecular condition by subjecting it to a heating process; e. g, by boiling it in water for a considerable length of time.

Although the viscous motion in metals is much smaller, it would, nevertheless, seem advisable to submit rods intended as *standards of length* to a thorough boiling in water prior to their final calibration, particularly when the metal is drawn or rolled.

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* Bulletin No. 73, 1891, U. S. Geological Survey.

Art. LI.—*On the Induction Coefficients of Hard Steel Magnets;* by B. O. Peirce.

In preparing a large number of deflecting magnets for the use of students in measuring by Gauss's method the intensity, *H*, of the horizontal component of the earth's magnetic field, I have had occasion to make several hundred measurements of the induction coefficients of seasoned magnets of different sizes and shapes. The results of this work have enabled me to predict with considerable accuracy what measurement would show the induction coefficients of various other magnets to be, and, since an approximate knowledge of the induction coefficient of a magnet is sufficient for many practical purposes, I hope that these results may prove useful to others.

A short account of the way in which the deflecting magnets were made will serve to show the scope of the observations and to explain some terms used in the sequel.

The fact that a great many sets of apparatus were required, each capable of giving accurate results, determined in some degree the character of this apparatus. It was desirable that no two of the deflecting magnets should be just alike, but it was essential that every one of them should be homogeneous and of such a form that its moment of inertia could be computed with an error less than $\frac{1}{5}$ per cent, corresponding to an error from this cause of $\frac{1}{10}$ per cent in a determination of *H*.

Notwithstanding their advantages, extremely slender magnets hardened in bundles like those which led to excellent results in the hands of Professor T. Gray,* were for several reasons unsuited to my purpose; accurately made hollow magnets would have been expensive, and it seemed best to use solid round rod magnets from $0{\cdot}8^{cm}$ to $0{\cdot}95^{cm}$ in diameter. Extremely homogeneous, round, polished drill rod of Stubs or Crescent steel was easily obtainable, and, to avoid as far as possible the necessity of grinding the hardened steel to form, the magnets were generally cut from long perfect specimens of this drill rod and the ends of the pieces were ground flat. The steel was then heated uniformly to a bright red by aid of a special gas-heater devised by Mr. G. W. Thompson, the mechanician of the Jefferson Laboratory, and immersed in a large bath of rapidly-stirred, ice-cold, acidulated water. In this way great uniformity was obtained in the hardening. The ends of the hardened pieces were very slightly ground again under water in a special holder on a Brown and Sharpe grinder. This gave a mirror surface at each end accurately perpendicular to the axis of the magnet without disturbing the temper in the

* A. Gray: Absolute Measurements in Electricity and Magnetism, ch. 2.

slightest degree. In most cases it was not necessary to grind the cylindrical surface true.

The hardened steel was either exposed to steam at 100° C. or immersed in boiling water for a long time, in order to "relax" the temper in the manner proposed by Messrs. Barus and Strouhal,* and each piece was then very slightly oiled while still hot. After this treatment the steel would still cut ordinary hard window glass.

The pieces were magnetized between the poles of a soft iron yoke in a long solenoid, having 32 turns of wire per centimeter of its length, by a current of about 25 amperes. By this arrangement it was possible to force through every piece of steel at least 18,000 lines of induction per square centimeter of the cross section.

The magnets were finally "seasoned," according to the directions of Messrs. Barus and Strouhal, by a second long exposure to boiling water or to steam at 100° C. Some magnets thus prepared have been repeatedly thrown upon the floor and one received about a hundred smart blows on end from a bar of magnetized steel without any perceptible loss of permanent magnetic moment.

A hundred magnets of the same size made in this way of the same kind of steel would be almost indistinguishable, but the inside of a thick piece of steel is evidently left a little less hard than the outer skin. The rate of change (with the length) of the specific magnetic moment of a very short seasoned magnet of given large cross section, sometimes decreases slightly as the length increases, and, in the case of some comparatively long pieces of thick steel, magnetization, contrary to the general rule,† increases the induction coefficient. It is easy to get various specific moments and great differences in the effective lengths of magnets of the same actual size made of steel wire hardened in a bundle.

Because most of the measurements of induction coefficients which I found recorded‡ were made either with unseasoned magnets or with magnets very different in shape from those which I was to use, I felt compelled not only to determine directly the induction coefficients of all the deflecting magnets but to test a large number of magnets made of other kinds of

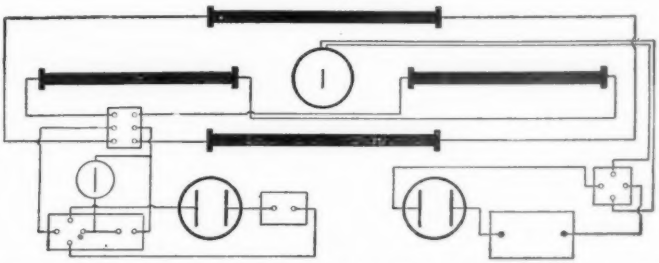
* Bulletin of the U. S. Geological Survey. No. 14, 1885.

† Ewing: Magnetic Induction in Iron and other metals, ch. vi.
Rayleigh: Phil. Mag., 1887.

‡ Kupffer: Pogg. Ann., 1828.
Lamont: Ann. d. Meteorologie und d. Erdmagnetismus, 1842.
Handbuch des Erdmagnetismus, 1849.
Wild: Ann. d. physikalischen Central-Observatoriums, 1878.
Bulletin d. l'Acad. Imp. d. Sc. d. St. Pétersbourg, 1880, 1883.
Repertorium für Meteorologie, 1883.
Mem. de l'Acad. Imp. d. Sc. d. St. Pétersbourg, 1886.
Kohlrausch: Wied. Ann., 1884.
Nachrichten d. k. Gesellschaft d. Wissenschaften, Göttingen, 1883.
H. Sack: Inaugural Diss., Frankfurt, 1886.

steel in order to find out whether any of these were much superior to magnets of similar shape made of drill rod. The determinations were made* with the aid of an induction bench two meters long furnished with two pairs of solenoids so placed and connected that a steady current passing successively through the coils of either pair would not deflect the magnetometer needle. This needle was closely surrounded by a small coil through which, in experimenting upon a magnet, a steady current could be sent just strong enough to balance the deflecting force of the magnet when placed in the center of any of the solenoids. The general arrangement of the apparatus appears in figure 1. The deflections of the magnetometer needle were measured by means of a telescope and scale; the strength of the weak current sent at any time through the solenoids, by a sensitive voltmeter in multiple arc with a standard resistance in the main circuit. The strength of the earth's magnetic field at the center of the magnetometer was known.

1.



After an unmagnetized specimen of hard steel had been inserted in the center of one of the solenoids, at a known distance from the magnetometer needle, a steady current so weak as not to leave any perceptible permanent magnetism† in the steel was sent through the solenoid. This current was reversed twenty times and then the deflection of the needle was measured for each direction of the current. With the customary correction‡ for the effective length of the steel, it was easy to compute the moment of the induced magnetism so that a similar measurement made in one of the other pair of solenoids would give practically the same result. Sometimes a number of measurements were made with the same specimen, using different magnetizing currents in order to make sure that the

* Maxwell: Treatise on Electricity and Magnetism. § 457.
Winkelmann: Handbuch der Physik, III. ii, p. 69.
Joule: Proc. Phil. Soc., Manchester, 1867.

† In the cases of some short pieces, a field of 3^{cgs} units was not too strong.

‡ Riecke: Wied. Ann., 1879.

limit had not been passed below which the induced moment was proportional to the strength of the magnetizing field. The induced moment was occasionally measured by balancing the deflecting action of the induced magnetism by means of a known current sent through a second small coil close to the magnetometer needle. The rather complicated apparatus is not shown in the diagram, for the method is not very convenient though it gives excellent results.

A steel bar magnet could be tested in the same manner as an unmagnetized bar, after the deflective effect of the permanent magnetism had been balanced by the help of a suitable steady current from the storage cell at the right of the diagram. The permanent magnetic moments of the seasoned magnets were determined on a long magnetometer bench in Gauss's "A position." Observations were made by myself and by Mr. C. G. Persons on several hundred pieces of steel at various stages on their way toward becoming seasoned magnets. The induction coefficients and the magnetic moments, though they were determined with some accuracy, are given only approximately in the subjoined tables, and I believe that most of them fairly represent what a second set of similar magnets would give.

It is proper to say that some of the Crescent drill rod of which I had a large quantity was obtained directly from the Crescent Steel Company of Pittsburg, but that much more was purchased of different dealers at different times. The Stubs and Jessops steels were also bought on various occasions of different dealers, and I venture to hope that my specimens fairly represent these steels. After testing large numbers of magnets made of Crescent polished drill rod and of Jessops round black tool steel I can only say that when hard these steels seem to be magnetically indistinguishable, though abnormal specimens occur. The Jessops steel is cheaper than the other but rougher and, as sold in the market, less thoroughly annealed. A stout magnet made of Stubs polished drill rod generally has a somewhat smaller permanent specific magnetic moment than a similar magnet made of either Crescent drill rod or of Jessops round tool steel, as appears from the results recorded in Tables I and II.

Table II represents observations made on a very large number of magnets. Each number in Table III, on the other hand, is based on measurements of only two specimens, cut from one of 21 sample rods very kindly furnished by the Crescent Steel Company. Table IV records tests made upon four odd magnets.

In order to compare more exactly relatively stout magnets made of Crescent drill rod, Stubs drill rod and Jessops round tool steel, I procured of an instrument maker a large number of hardened pieces of steel of each of these kinds, of

different lengths, but all 0·95^{cms} in diameter. It soon appeared that the hardening was not sufficiently uniform to serve my purpose, so I reheated and hardened all these pieces. This process, as was to be expected, injured the steel by increasing the induction coefficients and decreasing the permanent magnetic moments of the seasoned magnets. This appears from measurements given in Table V, in which the first four columns apply to all the pieces, but the last column only to the Jessops and Crescent steels, which were almost exactly alike after the rehardening. The permanent magnetic moments of the Stubs steel magnets were only about half those of corresponding magnets made of the other steels. The results of observations upon numerous pieces of Jessops square and flat tool steel appear in Tables VI and VII.

I have tested a number of magnets made of the "special magnet steels" of different makers. These all had, of course, relatively high permanent moments, but most of these steels are difficult to work and I have not yet been able to procure a sufficient quantity of any one of them, in shape suitable for the making of deflecting magnets, to enable me to compare the advantages of such magnets over those made of fine tool steel.

TABLE I.—*Magnets made of Round Polished Drill Rod.*

Brand.	Length in centimetre.	Diameter in centimeters.	Moment per gramme of the magnetism induced in the seasoned magnet when placed lengthwise in a unit field.	Permanent magnetic moment per gramme of the seasoned magnet.	Approximate ratio of the induced magnetic moment caused in the seasoned magnet by a unit field to the permanent moment of the magnet.
Crescent	12	0·64	0·23	27	0·009
Stubs	12	0·64	0·20	27	0·008
Crescent	12	0·48	0·21	31	0·007
Stubs	12	0·48	0·18	30	0·006
Crescent	12	0·30	0·22	36	0·006
Stubs	12	0·30	0·18	36	0·005
Crescent	10	0·64	0·19	25	0·008
Stubs	10	0·64	0·19	24	0·008
Crescent	10	0·48	0·19	30	0·006
Stubs	10	0·48	0·18	27	0·007
Crescent	10	0·30	0·20	30	0·007
Stubs	10	0·30	0·18	25	0·007
Crescent	8	0·64	0·20	20	0·010
Stubs	8	0·64	0·18	16	0·011
Crescent	8	0·48	0·19	21	0·009
Stubs	8	0·48	0·18	19	0·009
Stubs	6	0·80	0·15	10	0·015
Stubs	8	0·80	0·18	12	0·015
Stubs	10	0·80	0·20	14	0·014
Stubs	12	0·80	0·22	17	0·013
Stubs	15	0·80	0·24	21	0·011
Stubs	18	0·80	0·26	28	0·009
Stubs	20	0·80	0·27	35	0·008

TABLE II.—*Polished Crescent Steel Drill Rod.*

Length in centimeters.	Diameter in centimeters.	Weight in grammes per centimetre of length.	Moment per gramme of magnetism induced in the specimen when placed lengthwise in a unit field.				Permanent magnetic moment per gramme of the seasoned magnet	Approximate ratio of the induced moment caused by unit field to the permanent moment in the seasoned magnet.
			In the condition in which it was purchased.	When "glass-hard" but still unmagnetized.	When magnetized to saturation while "glass-hard."	In the condition of a seasoned magnet.		
20	1·11	7·6	0·44	0·23	0·28	0·30	30·5	0·010
18			0·41	0·22	0·26	0·28	25·5	0·011
16			0·38	0·21	0·24	0·25	21·5	0·012
14			0·34	0·20	0·22	0·23	17·5	0·013
12			0·29	0·19	0·19	0·20	15·0	0·014
10			0·25	0·17	0·17	0·18	12·0	0·015
8			0·20	0·15	0·14	0·15	10·0	0·015
6			0·15	0·13	0·11	0·11	8·5	0·015
4			0·11	0·08	0·08	0·08	5·5	0·017
20	0·95	5·5	0·50	0·23	0·25	0·26	36·5	0·007
18			0·48	0·23	0·24	0·25	32·5	0·008
16			0·45	0·22	0·23	0·24	28·0	0·009
14			0·42	0·21	0·21	0·22	24·0	0·009
12			0·37	0·20	0·19	0·20	20·5	0·010
10			0·31	0·18	0·17	0·18	17·0	0·011
8			0·25	0·16	0·15	0·16	14·0	0·012
6			0·19	0·13	0·13	0·13	10·0	0·013
4			0·12	0·09	0·10	0·10	7·0	0·014
20	0·80	3·9	0·61	0·24	0·24	0·30	41·0	0·007
18			0·58	0·23	0·23	0·29	36·5	0·008
16			0·54	0·22	0·22	0·28	32·5	0·009
14			0·49	0·20	0·20	0·27	26·5	0·010
12			0·44	0·18	0·18	0·26	24·0	0·011
10			0·39	0·16	0·16	0·24	20·0	0·012
8			0·31	0·14	0·14	0·21	17·0	0·012
6			0·23	0·12	0·12	0·16	13·0	0·014
4			0·15	0·09	0·09	0·12	8·5	0·014
20	0·64	2·4	0·69	0·26	0·23	0·25	43·0	0·006
18			0·65	0·25	0·23	0·24	38·0	0·006
16			0·61	0·24	0·22	0·24	33·5	0·007
14			0·56	0·23	0·21	0·23	28·0	0·008
12			0·49	0·22	0·20	0·22	23·0	0·009
10			0·42	0·21	0·19	0·21	19·0	0·010
8			0·33	0·19	0·17	0·18	15·0	0·012
6			0·25	0·16	0·13	0·15	11·0	0·014
4			0·16	0·11	0·10	0·10	7·0	0·014

TABLE III.—*Specimens (13·5 cm. long) of round "Crescent Tool Steel" of different brands.*

Brand.	Diameter in centimeters.	Approximate weight in grammes.	Moment per gramme of magnetism induced in the specimen when placed "lengthwise" in a magnetic field of unit strength.			Semi-permanent magnetic moment per gramme in the case of the "glass-hard" magnet.	Permanent magnetic moment per gramme in the case of the seasoned magnet.	Approximate ratio of the induced moment to the permanent moment in the case of the seasoned magnet.
			When "glass-hard" but not magnetized.	When magnetized to saturation while "glass-hard."	In the condition of a seasoned magnet.			
"D. R."	1·28	133·5	0·23	0·21	0·25	12	10	0·025
"	0·80	53·0	0·23	0·23	0·24	32	23	0·010
"	0·64	34·6	0·23	0·23	0·23	44	31	0·007
"	0·47	19·0	0·23	0·22	0·22	48	42	0·005
"	0·32	8·4	0·23	0·22	0·24	56	53	0·005
"Crucible Steel"	1·28	133·5	0·22	0·22	0·22	18	16	0·014
"	0·80	53·0	0·24	0·24	0·24	31	22	0·011
"	0·64	34·6	0·28	0·26	0·28	38	30	0·009
"	0·50	20·0	0·31	0·31	0·31	46	34	0·009
"Crescent Extra"	1·28	133·5	0·25	0·22	0·23	14	11	0·021
"	0·80	53·0	0·26	0·25	0·26	32	26	0·010
"	0·64	34·6	0·29	0·26	0·27	40	32	0·008
"	0·50	20·0	0·28	0·28	0·28	47	37	0·008
"Double Crescent"	1·37	157·0	0·23	0·21	0·22	11	9	0·024
"	0·80	53·0	0·25	0·24	0·24	39	28	0·009
"	0·64	34·6	0·28	0·25	0·25	43	32	0·008
"	0·52	21·2	0·28	0·27	0·29	48	41	0·007
"H. T. C."	0·80	53·0	0·30	0·30	0·30	21	31	0·010
"	0·64	34·6	0·34	0·32	0·32	51	42	0·008
"	0·53	22·5	0·36	0·32	0·32	63	51	0·006

TABLE IV.—*Tubular Magnets of Polished Crescent Drill Rod.*

Length in centimeters.	Outside diameter in centimeters.	Diameter of hole in centimeters.	Weight of magnet in grammes.	Moment per gramme of the magnetism induced in the seasoned magnet when placed lengthwise in a field of unit intensity.	Permanent magnetic moment per gramme of the seasoned magnet.	Approximate ratio of the induced magnetic moment in the seasoned magnet caused by a unit field to the permanent moment of the magnet.
10·2	1·28	0·94	42·9	0·23	23	0·010
7·6	1·28	0·94	31·8	0·20	16	0·012
7·1	0·95	0·70	14·8	0·22	20	0·011
5·2	0·95	0·70	11·1	0·21	15	0·014

TABLE V.—*Twice-hardened Round Tool Steel.*

Diameter in centimeters.	Length in centimeters.	Moment per gramme of the magnetism induced in the twice hardened but unseasoned and unmagnetized specimen when placed "lengthwise" in a unit field.	Moment per gramme of the magnetism induced in the twice hardened and seasoned magnet when placed "lengthwise" in a unit field.	Permanent magnetic moment per gramme of the twice hardened and finally seasoned magnet.
0·95	20	0·31	0·29	30·0
0·95	18	0·30	0·28	26·0
0·95	15	0.28	0·26	20·5
0·95	10	0·23	0·21	13·0
0·95	6	0·17	0·16	7·5
0·95	4	0·12	0·12	5·0

TABLE VI.—*Square Jessops Tool Steel.*

Length in centimeters.	Moment per gramme of magnetism induced in the specimen when placed "lengthwise" in a unit field.					Magnetic moment per gramme of the relaxed steel just after magnetization.	Permanent magnetic moment per gramme in the case of the seasoned magnet.	Approximate ratio of the induced moment caused by a unit field to the permanent moment in the case of the seasoned magnet.
	In the condition in which it was purchased.	When "glass-hard."	After the temper had been "relaxed" by exposure for 6 hrs. to steam at 100° C.	After the "relaxed" steel had been magnetized to saturation.	In the condition of a seasoned magnet.			
4	0·12	0·10	0·10	0·08	0·10	4·5	4·5	0·022
6	0·18	0·14	0·14	0·12	0·14	7·0	7·0	0·019
8	0·24	0·18	0·18	0·15	0·18	11·5	11·5	0·016
10	0·29	0·21	0·21	0·17	0·21	16·5	16·0	0·013
12	0·34	0·23	0·23	0·19	0·23	21·0	20·0	0·011
14	0·39	0·25	0·25	0·20	0·25	26·0	24·5	0·010
16	0·44	0·27	0·27	0·21	0·27	31·0	29·0	0·009
18	0·48	0·28	0·28	0·22	0·28	36·0	33·0	0·009
20	0·52	0·29	0·29	0·23	0·30	41·0	38·0	0·008

Cross-section = 0·67 sq. cm. Weight per cm. of length = 5·28 grammes.

TABLE VII.—*Jessops Flat Tool Steel.*

Length in centimeters.	Moment per gramme of magnetism induced in the seasoned magnet when placed "lengthwise" in a unit field.	Permanent magnetic moment per gramme of the seasoned magnet.	Approximate ratio of the induced magnetic moment caused in the seasoned magnet by a unit field to the permanent moment of the magnet.
6	0·18	11·0	0·018
8	0·22	15·0	0·015
10	0·24	18·5	0·013
15	0·29	27·5	0·011
20	0·33	36·5	0·009

Weight per centimeter of length = 3·9 grammes.
Cross-section = 1·6 cm. × 0·32 cm.

The Jefferson Physical Laboratory.
Cambridge, Mass., August, 1896.

ART. LII.—*On the Application of Certain Organic Acids to the Estimation of Vanadium;* by PHILIP E. BROWNING and RICHARD J. GOODMAN.

[Contributions from the Kent Chemical Laboratory of Yale University.—LIX.]

IN a former paper* by one of us a method for the determination of vanadium was described in which tartaric acid was used to reduce vanadic acid to the condition of the tetroxide. The method may be briefly outlined as follows:

Measured and weighed portions of a solution of ammonium vanadate, the standard of which had been determined by the evaporation and ignition of definite portions, were treated with tartaric acid in excess and boiled, when the appearance of the deep blue color indicated the reduction to the condition of the tetroxide. After cooling, the solution was neutralized with potassium bicarbonate and a moderate excess of that reagent added. To the alkaline solution an excess of a standard solution of iodine was added and the whole allowed to stand about one hour, when no further bleaching of the iodine was noticed.† The excess of iodine was then destroyed with a standard solution of arsenious oxide, starch was added, and the blue color obtained with a few drops of the iodine solution. The total amount of iodine used, less the amount equivalent to the arsenious oxide solution used, is the amount necessary to oxidize the vanadium from the condition of the tetroxide to that of the pentoxide, from which, according to the following equation, can be calculated the amount of vanadium present:

$$V_2O_4 + I - I + H_2O = V_2O_5 + 2HI.$$

The work to be described in this paper is in part an application of the work described in the paper above mentioned to a series of determinations of vanadium in the presence of molybdenum and tungsten. The solution of vanadium used was one of ammonium vanadate, and the standard was determined by evaporating and igniting, in the presence of a drop of nitric acid, measured and weighed portions, the mean of closely agreeing results being taken as the standard. Our first series of determinations was by the method previously described, that being the natural starting point for the work contemplated. The results follow in the table:

* Zeitschr. für anorgan. Chem. vii, 158.

† These determinations are best made in small Erlenmeyer beakers, closed with paraffin-coated cocks while standing with iodine.

	V_2O_5 taken. grm.	V_2O_5 found. grm.	Error. grm.	Tartaric acid. grm.
(1)	0·1621	0·1618	0·0003 —	2
(2)	0·1620	0·1624	0·0004 +	2
(3)	0·1614	0·1622	0·0008 +	2
(4)	0·1619	0·1606	0·0013 —	1
(5)	0·1604	0·1597	0·0007 —	2
(6)	0·1618	0·1615	0·0003 —	3
(7)	0·1298	0·1305	0·0007 +	1
(8)	0·1294	0·1297	0·0003 +	1
(9)	0·1618	0·1618	0·0000 ±	2
(10)	0·2588	0·2575	0·0013 —	3
(11)	0·2722	0·2726	0·0004 +	2
(12)	0·3273	0·3269	0·0004 —	2

We next tried the effect of treating a solution of sodium tungstate in the same manner. We found that after the boiling with tartaric acid, neutralizing, adding iodine and allowing to stand as before, the amount of free iodine present, as shown by the amount of arsenious oxide solution necessary to destroy it was the same as that originally added, showing that no reduction had taken place. Accordingly a series of determinations of vanadium in the presence of tungsten was made which is recorded in the following table:

	V_2O_5 taken. grm.	V_2O_5 found. grm.	Error. grm.	Sodium tungstate. grm.	Tartaric acid. grm.
(1)	0·1618	0·1615	0·0003 —	1	3
(2)	0·1615	0·1606	0·0009 —	1	3
(3)	0·1618	0·1624	0·0006 +	1	3
(4)	0·1619	0·1624	0·0005 +	1	3
(5)	0·1627	0·1623	0·0004 —	1	3
(6)	0·1621	0·1624	0·0003 +	1	4
(7)	0·2587	0·2574	0·0013 —	1	4
(8)	0·2587	0·2589	0·0002 +	1	4

The results above show that vanadium may be easily determined by this method in the presence of tungsten without any evident interfering action on the part of the latter element.

When the same method of treatment was applied in the presence of molybdenum in the form of ammonium molybdate, the majority of the determinations gave large plus errors, and a few experiments made with the molybdate alone seemed to show a noticeable reduction of the molybdic acid. In the following table the results are tabulated. In experiments (3), (4) and (5) the mixtures were not boiled with tartaric acid, but warmed on a steam bath, with, however, no very apparent prevention of the reducing action.

	V_2O_5 taken. grm.	V_2O_5 found. grm.	Error. grm.	Ammonium molybdate. grm.	Tartaric acid grm.
(1)	0·1620	0·1790	0·0170 +	1	2
(2)	0·1624	0·1619	0·0005 —	1	2
(3)	0·1294	0·1416	0·0253 +	1	2
(4)	0·1296	0·1361	0·0065 +	1	2
(5)	0·1291	0·1312	0·0021 +	1	2
(6)	0·1293	0·1324	0·0031 +	1	2
(7)	0·1636	0·1760	0·0124 +	1	2
(8)	0·1640	0·1724	0·0084 +	1	2
(9)	0·1622	0·1624	0·0002 +	1	3
(10)	0·1622	0·1632	0·0010 +	1	3
(11)	0·1619	0·1879	0·0260 +	1	3
(12)	0·1292	0·1360	0·0068 +	1	3
(13)	0·1860	0·1917	0·0057 +	1	3
(14)	0·3274	0·3733	0·0459 +	1	4
(15)	0·2324	0·2383	0·0059 +	1	4

We next tried the action of tartaric acid upon the vanadium solution in the cold and found that the reduction could be carried on to completion under these conditions if the tartaric acid was in large excess, the time sufficient and the volume of the solution small. The following series was made to determine these points:

	V_2O_5 taken. grm.	V_2O_5 found. grm.	Error. grm.	Time. days.	Tartaric acid. grm.	Total vol. cm^3.
(1)	0·1646	0·1649	0·0003 +	1	4	25
(2)	0·1640	0·1606	0·0034 —	1	4	65
(3)	0·1293	0·1264	0·0029 —	2	3	55
(4)	0·1633	0·1628	0·0005 —	2	4	65
(5)	0·1293	0·1288	0·0005 —	3	2·5	50
(6)	0·1298	0·1299	0·0001 +	3	2·5	50
(7)	0·1295	0·1279	0·0016 —	3	3	55
(8)	0·1617	0·1597	0·0020 —	4	2	70
(9)	0·1623	0·1622	0·0001 —	4	3	80

Solutions containing sodium tungstate and ammonium molybdate were allowed to stand from one to four days with varying amounts of tartaric acid without giving any evidence of reduction.

In the series which follows may be seen the results of a number of determinations of vanadium in the presence of molybdenum and tungsten made in the cold and allowed to stand from one* to four days. It will be noticed that the results on standing one day with five grams of tartaric acid are

* Some of the determinations designated in the table as having stood one day in reality stood only about fifteen hours, from 6 P. M. to 9 A. M.

for the most part satisfactory, and an increase in the length of time does not cause any apparent reduction of the molybdenum.

	V_2O_5 taken. grm.	V_2O_5 found. grm.	Error. grm.	Ammonium molybdate. grm	Sodium tungstate. grm.	Time in days.	Total volume. cm^3.	Tartaric acid. grm.
(1)	0·1552	0·1558	0·0006+	--	--	1	25	5
(2)	0·1289	0.1301	0·0012+	--	--	1	25	5
(3)	0·2583	0·2587	0·0004+	--	--	1	50	5
(4)	0·1293	0·1299	0·0006+	1·	--	1	25	6
(5)	0·2582	0·2591	0·0009+	1·	--	1	50	6
(6)	0·2582	0 2588	0·0006+	1·	--	1	50	5
(7)	0·1297	0·1308	0·0011+	1·	--	1	25	5
(8)	0.1291	0·1289	0·0002—	--	1	1	25	6
(9)	0·2582	0·2568	0·0014—	--	1	1	50	5
(10)	0·1293	0·1299	0·0006+	1·	1	1	25	8
(11)	0·2582	0·2579	0 0003—	1·	1	1	50	5
(12)	0·1550	0·1538	0·0012—	--	--	2	25	5
(13)	0·1556	0·1545	0·0011—	--	--	2	25	5
(14)	0·1289	0·1296	0·0007+	--	--	2	25	5
(15)	0·1549	0·1527	0 0022—	0·5	--	2	25	5
(16)	0·1553	0·1548	0·0005—	1·	--	2	25	5
(17)	0·1556	0·1554	0·0002—	1·	--	2	25	5
(18)	0·1293	0·1310	0·0017+	1·	--	2	25	6
(19)	0·1295	0·1299	0·0004+	--	1·	2	25	6
(20)	0·1293	0·1289	0·0004—	1·	1·	2	25	7
(21)	0·1293	0·1301	0·0008+	--	--	3	25	5
(22)	0·1289	0·1299	0·0010+	0·5	--	3	25	5
(23)	0·1293	0·1292	0·0001—	1·	--	3	25	7
(24)	0·1556	0·1567	0·0011+	1·	--	3	30	5
(25)	0·1291	0·1289	0·0002—	1·	1·	3	25	7
(26)	0·1550	0·1557	0·0007+	--	--	4	25	5
(27)	0·1554	0·1557	0·0003+	1·	--	4	25	5
(28)	0·1556	0·1557	0·0001+	0·5	--	4	25	5

Friedham* has shown that vanadium is reduced from the condition of the pentoxide to that of the tetroxide by boiling with oxalic acid. The reduction is so complete that he has developed a method for the estimation of vanadium upon this reaction and shows that it may be applied in the presence of molybdenum and tungsten, the acids of these elements not being reduced by the oxalic acid. When the vanadic acid is reduced the oxalic acid is oxidized and a definite amount of carbon dioxide evolved according to the reaction.

$$V_2O_5 + H_2C_2O_4 = V_2O_4 + H_2O + 2CO_2.$$

This carbon dioxide Friedheim conducts by an appropriate

* Zeitschr. für anorgan. Chem. i, 312.

form of apparatus into potassium hydroxide and weighs. From this weight the amount of vanadic acid originally present may be readily calculated.

We have applied the method of oxidation with standard iodine described in the tartaric acid process to the residue after boiling with oxalic acid. The method of treatment was identical with that outlined at the beginning of this paper. The results which follow in the table are for the most part satisfactory and the method is certainly more easily applied than Friedheim's process, the potassium hydroxide absorption apparatus being unnecessary.

	V_2O_5 taken. grm.	V_2O_5 found. grm.	Error. grm.	Oxalic acid. grm.	Ammonium molybdate. grm.	Sodium tungstate. grm.
(1)	0·1806	0·1803	0·0003 —	1		
(2)	0·1950	0·1955	0·0005 +	1		
(3)	0·1959	0·1955	0·0004 —	1		
(4)	0·1950	0·1959	0·0009 +	1		
(5)	0·1954	0·1977	0·0023 +	1		
(6)	0·1956	0·1960	0·0004 +	1		
(7)	0·1956	0·1964	0·0008 +	1		
(8)	0·1956	0·1957	0·0001 +	1		
(9)	0·3900	0·3899	0·0001 —	2		
(10)	0·3897	0·3917	0·0020 +	2		
(11)	0·3903	0·3905	0·0002 +	2		
(12)	0·1954	0·1959	0·0005 +	2	1	
(13)	0·1957	0·1960	0·0003 +	2	1	
(14)	0·1954	0·1961	0·0007 +	2	1	
(15)	0·1806	0·1818	0·0012 +	3	--	
(16)	0·1807	0·1827	0·0020 +	3	--	
(17)	0·1809	0·1803	0·0006 —	3	1	
(18)	0·1956	0·1961	0·0005 +	3	--	1
(19)	0·3611	0·3617	0·0006 +	5	--	--
(20)	0·3616	0·3626	0·0010 +	5	1	--

Having applied successfully both tartaric acid and oxalic acid in the manner described, the action of citric acid applied in the same manner suggested itself as a fitting conclusion to the study of the action of this class of organic acids In this case, as in the others, the reduction of the vanadic acid is easily and quickly effected, but the oxidation with the iodine is slower than in the presence of alkaline oxalates and tartrates. In the case of oxalic acid on standing about fifteen minutes with the excess of iodine, when tartaric acid has been used, the bleaching of the iodine continues from thirty to forty-five minutes, but in the presence of the alkaline citrate the time required is fully an hour. A large excess of tartaric or oxalic acids does not seem to materially affect the results,

but in the use of citric acid it is advisable to avoid a large excess, which tends to give high results. Accordingly in the following series of experiments it will be noticed that the amounts of citric acid do not exceed two grams except where ammonium molybdate or sodium tungstate are present, when the ammonium or sodium base combines with part of the free acid. The results follow:

	V_2O_5 taken. grm.	V_2O_5 found. grm.	Error. grm.	Citric acid. grm.	Ammonium molybdate. grm.	Sodium tungstate. grm.
(1)	0·1956	0·1956	0·0000±	1		
(2)	0·3905	0·3921	0·0016+	2		
(3)	0·1960	0·1960	0·0000±	1		
(4)	0·1953	0·1960	0·0007+	1		
(5)	0·2088	0·2082	0·0006—	2		
(6)	0·2100	0·2098	0·0002—	2		
(7)	0·2092	0·2107	0·0015+	1		
(8)	0·2092	0·2107	0·0015+	2		
(9)	0·2096	0·2082	0·0014—	2	0·5	
(10)	0·2099	0·2116	0·0017+	3	0·5	--
(11)	0 2005	0·2101	0·0006+	2	--	0·5
(12)	0·2099	0·2095	0·0004—	3	--	0·5

The mode of proceeding in the estimation of vanadium by the use of either tartaric, oxalic or citric acids may be briefly summarized as follows: To a solution of a vanadate with or without a tungstate or molybdate, add approximately one gram of the acid for every tenth of a gram of substance to be determined. Heat the solution to boiling, except in case tartaric acid be present with molybdic acid, when digestion for from fifteen to twenty-four hours in the cold should be substituted. To the cold liquid add about five grams of potassium bicarbonate for every gram of acid used. Add iodine in slight excess and set aside until no further bleaching is noticeable. Destroy the excess of iodine with arsenious oxide solution, add starch, and titrate back with standard iodine. The total amount of iodine used less the equivalent of the arsenious oxide is the measure of the oxidation.

I have found it of advantage, when starting with a new solution of the vanadate, to make one determination roughly and to get from this rough determination the proportions of acid and iodine to be used in the determinations to follow. Large amounts of the acid and a large excess of the iodine have been employed in many determinations without any apparent unfavorable effect upon the results. The tendency, however, under these circumstances is toward plus errors, which may be avoided by following the above directions.

June, 1896.

ART. LIII.—*The Determination of Oxygen in Air and in Aqueous Solution;* by D. ALBERT KREIDER.

[Contributions from the Kent Chemical Laboratory of Yale University, LX.]

WHILE there is little to be hoped for by way of improvement in the accuracy of present known methods for the determination of oxygen in the air, some choice as to manipulation may nevertheless be desirable, and a process which is not limited wholly to the methods and apparatus of ordinary gas analysis will doubtless often be found serviceable.

The very satisfactory results which I have obtained in the determination of perchlorates by the action of the liberated oxygen upon hydriodic acid through the medium of nitric oxide* has led me to test this action upon the oxygen of the air, where only the smaller amount of oxygen and its greater dilution with nitrogen might be expected to be unfavorable. However with the apparatus and manipulation herein described it will be seen that the method affords a means for the determination of the oxygen of the air or of dissolved oxygen with ease and rapidity and with sufficient accuracy for all practical purposes.

The method in brief is simply the conducting of a known volume of air through a strong solution of hydriodic acid in the presence of nitric oxide; subsequently neutralizing the acid with potassium bicarbonate and titrating the liberated iodine with standard decinormal arsenic solution from which the equivalent volume of oxygen is readily calculated. By several simple devices, to be described, all calculations may be done away with and the percentage of oxygen seen immediately by the volume of arsenic solution required for the titration.

The volume of oxygen found by means of the arsenic solution is, of course, under the standard conditions of temperature and pressure (0° and 760^{mm}), and it is therefore essential either to calculate this volume into that which it would occupy under the conditions of the experiment, or to reduce to the standard conditions of temperature and pressure the volume of air taken. The latter plan is the more satisfactory since by Lunge's ingenious device† the reduction can be readily effected without any calculation and independently of changing temperature and pressure. For my purpose the following arrangement of two burettes answered admirably. One burette graduated to 120^{cm^3} contained over mercury the same

* This Journal, I, 287. † Zeitschr. für Ang. Chem. 1890, 139.

volume of moist air which 100^{cm^3} of air at 0° and 760^{mm} would occupy under the given conditions; this standard being very carefully determined. By means of a T-tube this standard burette was placed between and in connection with the burette in which the volume of air to be analyzed was measured, and a movable reservoir of mercury. Both burettes were firmly fastened to a movable iron rod and the zero marks accurately adjusted to the same level. By drawing into the measuring burette a volume of air greater than that required—for which purpose a small bulb was attached to the lower end of the burette, and then by raising the reservoir of mercury, compressing the air in the standard tube to the 100^{cm^3} mark, at the same time allowing the excess of air to escape from the measuring burette, exactly 100^{cm^3} of air under the standard conditions of temperature and pressure was obtained. To facilitate the adjustment, two strips of wood were fastened to the rubber connection by means of screw pinch-cocks in such a way that by closing one pinch-cock the flow of mercury from the reservoir could be shut off, and then by gradually tightening the other pinch-cock the mercury would be forced out of the rubber, and thus an easy and accurate adjustment to the 100^{cm^3} mark be secured.

The apparatus in which the action of the oxygen upon hydriodic acid was effected consisted of a 300^{cm^3} bulb pipette, both ends of which were cut off short and sealed to glass stop-cocks. The tube from one of the stop-cocks was cut off short after being tapered and restricted so as to hold a rubber connector tightly, while the tube from the other stop-cock was left sufficiently long to reach to the bottom of a 500^{cm^3} Erlenmeyer beaker. These tubes are preferably of about 3^{mm} bore, since for the several connections all air may be expelled from tubes of this size by displacement with water. In order to expel all air from the flask, instead of passing a current of carbon dioxide as was done in the determination of perchlorates, time was saved by first filling the flask with water, which was then displaced by pure carbon dioxide (prepared as described below) and the flask subsequently exhausted, which was accomplished instantaneously by the device described in the article on perchlorates. The required amounts of potassium iodide solution, hydrochloric acid and nitric oxide were drawn in in the order named, after which the measured volume of air was gradually admitted while the bulb was constantly agitated so as to keep the hydriodic acid continually renewed along the surface of the bulb. The shaking was continued for a minute or two until the action was completed, when a dilute solution of potassium bicarbonate was admitted. The

carbon dioxide liberated forces the liquid from the bulb into a beaker which contains bicarbonate in amount sufficient, as previously determined, to neutralize all the acid taken. When the exit is too slow more bicarbonate may be admitted through the other stop-cock, and after neutralization has been completed the bulb may be washed out without any danger from the admission of air.

All the water employed, both for the solution of potassium iodide and for the various connections, was free of oxygen. It was prepared by filling a three liter flask with distilled water and boiling until the volume of the liquid was reduced about one-third, when the flask was closed by a doubly perforated rubber stopper and fitted as a wash bottle. By means of the tube which reached below the surface of the water, pure carbon dioxide was passed through while the water was still boiling, which together with the escaping steam was sure to expel all oxygen. Then the heat was removed and the current of carbon dioxide continued until the boiling ceased, when the escape tube was closed by a piece of rubber tubing and screw pinch-cock. As the water cooled it was well shaken while still in connection with the carbon dioxide generator, and thus became saturated with the gas, which was then pumped in under considerable pressure by the little hand pump described in a previous paper from this laboratory. By this means the water could be drawn as needed without the introduction of any air. The escape tube was provided with a rubber tube and screw pinch-cock, and a long, slender nozzle which could be inserted into the tubes of the absorption apparatus. A bottle thus charged sufficed for all the determinations and required only an occasional supply of carbon dioxide when large draughts of water were required for making the potassium iodide solution.

The potassium iodide solution was made up to contain one gram of the salt in thirty cubic centimeters of water, and was contained in convenient form in an ordinary wide-mouthed bottle fitted as a wash bottle, and graduated approximately for each thirty cubic centimeter's volume—the amount usually taken. The potassium iodide was weighed into the bottle, which was then closed and all air expelled by a current of carbon dioxide, when the desired amount of water, free of oxygen, was drawn in, and attachment again made with the carbon dioxide generator. After allowing the gas to pass for several minutes the exit was closed and the gas pumped in by the little hand pump. Inasmuch as this solution, when it was used, was drawn into an exhausted bulb, the bottle could be emptied without ever exposing its contents to the air.

Nitric oxide was generated very satisfactorily according to Professor Gooch's method—by the action of nitric acid upon globules of copper in a Kipp generator. When the nitric acid is diluted with an equal volume of water the evolution of the gas is sufficiently rapid without the application of heat, but contamination by the higher oxide is more likely. However, since it is necessary, in order to be certain of purity, to pass the gas through an acidified solution of potassium iodide before applying it to the determination of oxygen, whatever higher oxide may be present will be reduced. By passing the gas, as it issued from the generator, through a set of Geisler bulbs containing an acidified solution of potassium iodide and washing with potassium iodide solution, the perfectly purified gas was obtained. Theoretically, only a small amount of the nitric oxide is required for the transference of the oxygen to the hydriodic acid, but when too little is taken the action is very slow. On the other hand, too large an amount relieves the vacuum to such an extent as to interfere with the introduction of the air. A little device to measure the volume of gas taken was therefore attached to the generator. It consisted of a tube filled with water and roughly graduated for every five cubic centimeters, so attached to the generator that the gas would enter by displacement of the water, which would descend to a lower bulb, and as the gas was withdrawn the water would again take its place. Fifteen cubic centimeters of the gas was found a convenient and satisfactory amount for the analysis.

Carbon dioxide was generated in a Kipp generator, the acid and marble of which had been previously boiled and contained a little cuprous chloride. To remove a trace of reducing matter which the gas was found to contain, it was first passed through a solution of iodine and washed with potassium iodide.

For the titration a decinormal solution of arsenious oxide (4·95 gms. to the liter) was employed: one cubic centimeter being equal to 0·559846$^{cm^3}$ of oxygen at 0° and 760^{mm} when the weight of a liter of oxygen at 0° and 760 ^{mm} is taken as 1·42895 gms. When the volume of air taken is 100$^{cm^3}$ under standard conditions of temperature and pressure, as obtained by Lunge's device, the following table, calculated for the volume of oxygen equivalent to the volume of arsenic solution, shows directly the percentage of oxygen corresponding to the reading of the burette. The correction necessary for the fraction of a tenth of a cubic centimeter of the arsenic solution is obtained with sufficient accuracy by simply multiplying by 0·005.

Relation of Arsenic to Oxygen.

$\frac{n}{10}As_2O_3$. cm³.	Oxygen equivalent at 0° and 760mm. cm³.	Correction for 0·01 cm³ $\frac{n}{10}As_2O_3$.
37·0	20·714	0·005
37·1	20·770	
37·2	20·826	
37·3	20·882	
37·4	20·938	
37·5	20·994	
37·6	21·050	
37·7	21·106	
37·8	21·162	
37·9	21·218	
38·0	21·274	

Table I shows the results obtained in a series of determinations. Experiments 1 to 11 inclusive were made upon portions of air collected over water on March 28, measured in an ordinary gas burette and reduced to the standard conditions of temperature and pressure. The remainder of the determinations were made upon air collected on April 8th, each portion having been measured in the apparatus described, for the reduction to standard conditions.

TABLE I.

	Vol. of Air reduced to 0° and 760mm. cm³.	$\frac{n}{10}As_2O_3$ required. cm³.	Vol. of Oxygen found at 0° and 760mm. cm³.	Per cent of Oxygen in Air.
1.	91·18	34·06	19·07	20·91
2.	91·73	34·47	19·30	21·04
3.	90·84	34·25	19·17	21·11
4.	90·60	34·20	19·16	21·13
5.	86·06	32·55	18·22	21·17
6.	85·96	32·40	18·14	21·10
7.	86·49	32·53	18·21	21·06
8.	87·85	33·00	18·47	21·03
9.	44·17	16·60	9·29	21·04
10.	44·11	16·70	9·35	21·19
11.	44·54	16·80	9·41	21·12
12.	100·00	37·44	20·96	20·96
13.	100·00	37·54	21·01	21·01
14.	100·00	37·50	20·99	20 99
15.	100·00	37·57	21·03	21·03
16.	100·00	37·47	20·97	20·97
17.	100·00	37·50	20·99	20·99

No correction was found necessary for the blank determinations, since when boiled water was used the solution was only faintly colored with iodine, which requires only a drop of arsenic solution to bleach it. As is evident from the table, the determinations according to this method are not reliable beyond 0·05 per cent, but for practical purposes this is sufficiently accurate. For the sake of comparison two determinations by the pyrogallic acid method were made upon a portion of the same air used in the last experiments, the results being 20·93 and 20·88 per cent respectively. While the pyrogallic acid method is capable of much greater accuracy when applied in Hempel's improved apparatus, in ordinary burettes it will probably not yield more closely agreeing results than the above method.

Determination of dissolved Oxygen.—A determination of oxygen dissolved in water can be completed by the above method in about ten minutes by means of the apparatus illustrated by the accompanying figure.

The apparatus consisted of a flask of about 300$^{cm^3}$ capacity, into the bottom of which was sealed a stop-cock with a long exit tube. Upon the neck was cut the fiducial circle *c* and immediately above this stop-cock *e* was sealed as shown. The neck of the flask was drawn out and sealed to stop-cock *d* and the bulb, *a*, of about 30$^{cm^3}$ capacity blown in it. The capacity of the apparatus between stop-cock, *b*, and the fiducial mark, *c*, was carefully determined.

The manipulation for the determination of dissolved oxygen was as follows: The flask was held in the position shown by a clamp fastened to a movable support. Stop-cock *b* being closed, the water was admitted through *e* and the air allowed to escape through *d* until the level of water was that indicated by the line *f*. (When the water to be examined is not saturated with air, the flask must first be filled with carbon dioxide and the water entered by replacement of that gas.) With *d* closed, sufficient water was allowed to escape through *b* to bring the surface to *e*, which was then closed. The nitric oxide generator was then attached to *d*, and by opening *b* the gas was allowed to replace the water until the meniscus coincided with *c*, when *d* was closed and the generator disconnected. Two cubic centimeters of strong hydrochloric acid were introduced through *e* by expelling nitric oxide through *d*, in which a drop of water formed an effective trap to prevent the entrance of air. Then the potassium iodide was admitted in the same way. The solution of iodide for this purpose was free of oxygen and contained one gram in three cubic centimeters. It was kept under pressure of carbon dioxide in the bottle previously

described, and by means of a long nozzle could be conducted to the bottom of *eh* and thus be admitted with but momentary and slight contact with the air. The tube *eh* contained approximately three cubic centimeters. With all the stop-cocks closed, the flask was inverted several times and thoroughly shaken, at the same time washing out the ends of the stop-cocks with distilled water. After again placing the apparatus in its position, enough potassium bicarbonate solution was admitted through *e* to expel all the nitric oxide through *d*; the bulb, *a*, holding sufficient of the bicarbonate to neutralize all the acid taken. The bicarbonate being heavier quickly diffuses through the contents of the flask and neutralizes the acid; *d* and *e* are kept closed for a minute with *b* open so as to allow sufficient of the liquid to escape into a beaker containing some bicarbonate to provide space for the carbon dioxide evolved. Then the flask is washed out and its contents titrated with arsenic.

The bleaching, by the aid of starch for the final reaction, can be accurately read to a single drop. Usually the reading was verified by adding a drop of $\frac{N}{10}$ iodine solution, which produced the characteristic color.

Table II gives the results of a series of determinations.

TABLE II.

Vol. of Water taken. cm^3.	Temperature. —° C.	As_2O_3 required. cm^3.	Vol. of Oxygen dissolved in 1000 cm^3 of water at 760^{mm}.
314·63	20	3·42	6·04
"	"	3·45	6·09
"	"	3·40	6·00
"	"	3·41	6·02
"	"	3·43	6·05
"	"	3·40	6·00
"	"	3·36	5·93
"	"	3·40	6·00
"	"	3·40	6·00
"	"	3·50	6·18
"	"	3·38	5·96
"	"	3·40	6·00

The mean of these determinations gives $6·022^{cm^3}$ of oxygen as the amount dissolved in distilled water at 20° C. and 760^{mm}, and while some of the determinations vary considerably from this mean, as a whole they are fairly accordant. This method, moreover, is applicable to carbonated water.

ART. LIV.—*Local Deformation of Strata in Meade County Kansas and Adjoining Territory (Preliminary)*;* by ERASMUS HAWORTH.

WHILE making geological investigations in Meade and adjoining counties in western Kansas during the summer of 1896, the writer found certain conditions which seem to be best explained by the conclusion that a fault of considerable magnitude exists in Meade county, a fault decidedly larger than any other one known in the state, and hence worthy of this preliminary notice.

Kansas occupies a middle position in the great plains between the Rocky Mountain system and the Mississippi River. Its eastern limit is about 200 miles west of the river, and its western border—400 miles away—is a like distance east of the easternmost part of the Rockies. Nowhere in the state has there yet been found marks of vigorous orographic movements, although in many localities slight faults and gentle flexures are known.

The general conditions of deformation in the plains to the north and south of Kansas are about the same as within the state, while both east and west such conditions are more strongly marked. The movements to the east and southeast in Missouri which produced the Ozark uplift, and a similar though more pronounced uplift in Arkansas, extended in a milder form to eastern Kansas, as is abundantly shown by the numerous fissures and faults of slight dislocation and the gentle flexures so common to that part of the state. To the west in eastern Colorado, as the Rocky mountains are approached, disturbances are much more common and more marked in degree, as is well known to geologists generally.

(a). *Geographic evidences of deformation.*

By referring to the accompanying map the general geography of the district under consideration may be understood. Crooked Creek, the stream most affected by the fault, rises in the extreme eastern part of Haskell county and flows almost due east to near the little village of Wilburn. Here it suddenly turns to the southwest, making an angle of about forty-five degrees with itself, to about twelve miles south of Meade, where it veers southeastward to its junction with the Cimarron river. The bluff lines along Crooked Creek are quite interesting in character, particularly below Meade. Throughout the portion

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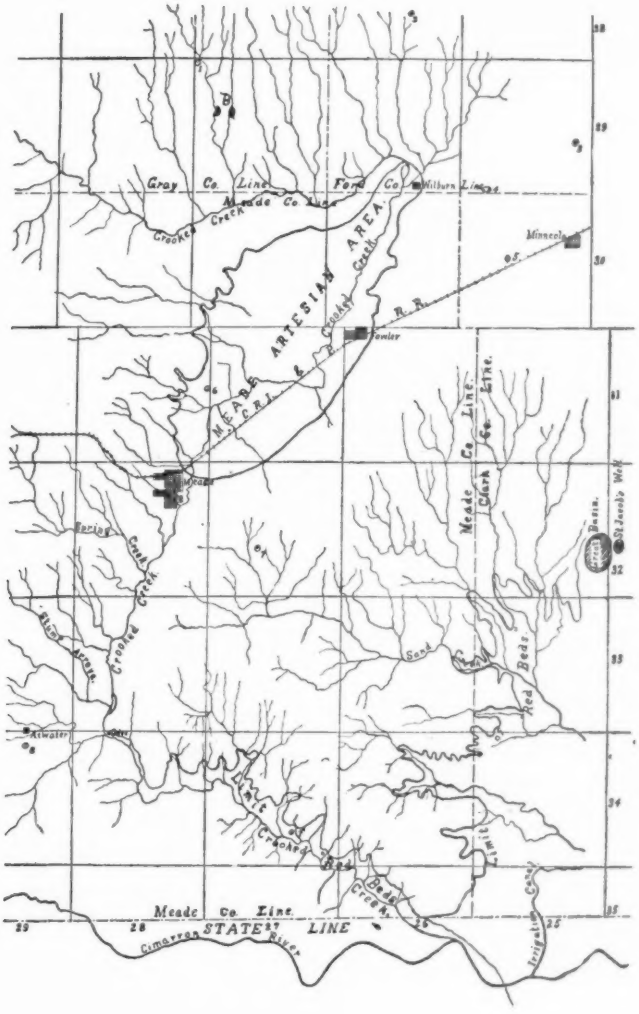


Map of Meade County, Kansas. Showing location of the Meade artesian valley and drainage of contiguous areas, largely copied from U. S. topographic maps, by Erasmus Haworth.

of its course where it flows east the bluffs on either side of the creek are not especially different from the ordinary. Tributaries from the north are most numerous but quite a number are found entering the creek from the south in the northwestern part of Meade county. Farther east, opposite the artesian area, no tributaries of any consequence are found on the south, while arroyas of greater or less size are found every mile or two on the north. For twenty miles below the sharp angle at Wilburn scarcely a tributary as much as two miles in length enters from the east, while the drainage streams flowing southeast to the Cimarron rise almost on the verge of the eastern bluffs of Crooked Creek. Throughout this distance many tributaries enter from the west, the most important being Spring Creek, about twelve miles long, and Stump arroya, nearly as long.

The general character of the uplands is that of a broad plain inclined to the southeast about ten feet to the mile. The various drainage channels are cut down into this plain, generally producing abrupt bluffs on each side. From Wilburn to Meade, however, the bluffs of Crooked Creek are far apart, with the whole of the artesian area between. Below Meade the bluffs on the east side of the creek are high and abrupt, often being almost precipitous in character. They have a decidedly new appearance, as though the erosion which produced them was very modern. Almost none of the rounded forms of old age are to be found, but the angular points and steep walls of recent formation are everywhere present. On the western side there is a gently sloping plain stretching from the creek to from one to five miles away, producing an appearance scarcely duplicated within the state. The general upland plain from eight to twelve miles to the west of Crooked Creek both physiographically and geologically corresponds with the plain on the east of the creek, which approaches to within less than a quarter of a mile of the creek valley. The general appearance from Meade southward is that of a fault with the western wall dropped and Crooked Creek occupying a position over the fault line. Northward the whole artesian valley seems to have been dropped downwards, leaving an abrupt wall on the west, and a more gentle wall on the east. Standing anywhere in the valley one can see the wall all around him. On the west it is considerably over a hundred feet in height, while to the east it is some less, but still very perceptible. We have here a valley occupying almost twenty square miles which is so different from anything else known in this part of the country that it is exceedingly difficult to explain its origin by any system of erosion. The peculiar position of the creek is likewise hard to explain by any ordinary conditions of erosion. The sharp angle at

Wilburn and the southwestern direction for nearly twenty miles across a plain sloping to the southeast are certainly very remarkable, and probably have a cause different from that which ordinarily determines the location and direction of a stream. But if in post-Tertiary times a triangular area equalling in size and position the present artesian area could have dropped a hundred feet or more with a single fault line extending southward to beyond the limits of Kansas, thereby changing the direction of Crooked Creek into the present channel below Wilburn, the general physiographic conditions could easily be accounted for.

It should be added that there is a chain of wet-weather lakes reaching eastward from Wilburn to the north of Minneola which may represent the former channel of the eastward extension of Crooked Creek. An examination of the country lends more color to this view than can be gained from the U. S. topographic sheets, for the twenty-foot contour lines often fail to represent physiographic conditions of great importance in such studies as these.

Other lesser disturbances have occurred in this locality. About one and a half miles south of Meade, on the eastern bluff of Crooked Creek a sink hole a hundred feet across, thirty or more feet deep, and almost circular in form was formed, tradition has it, less than thirty years ago. It is reported that a trail formerly passed directly over the sink hole. A very strong brine now fills the bottom of the hole, the salt probably having been obtained from the adjoining Tertiary clays, which are perceptibly saline. It would seem that this is an ordinary sink hole caused by portions of the sub-surface materials having been carried away by solution.

A few miles to the southeast of this area in western Clark county other indications of local disturbances are found. A broad and level valley more than a mile across and nearly circular in outline seems to have been dropped vertically for about a hundred and fifty feet. This is locally called the great basin. On the east of it a hundred yards is a similar valley a fourth as large, which likewise seems to have been dropped a like distance. In the northern part of this latter valley a sink hole about seventy-five feet across now holds fresh water with a maximum depth of twenty-seven feet. This is locally called St. Jacob's well, and is so marked on the U. S. topographic sheets.

These two areas are so large that it is difficult to understand how they can be classed as ordinary sink holes, as the Meade salt well may be. Their origin should be looked upon as due to some greater movements, possibly similar in character to that which produced the artesian valley near Meade, although no connecting fault has yet been located.

(b.) *Geologic evidences of deformation.*

The general geology of this part of the state is now pretty well understood. Excepting a small area in the southeast the whole surface is covered with the Tertiary sands and clays. In the northern part of the area these rest directly on the Benton limestone and shales, which gradually thin out and entirely disappear in the northern part of Meade county. Below the Benton lies the Dakota, which also thins southward and disappears near the middle of the county. As these formations are usually entirely covered by the Tertiary, we know of their presence only by well records, therefore their exact southern limits cannot well be stated. South of this the Tertiary rests directly on the "Red-Beds," as is abundantly shown by many exposures in the vicinity of Englewood and along Crooked Creek, and by well records on the plains east of Crooked Creek.

Along the northern side of Crooked Creek, in township 29 south, ranges 27 and 28 west, the Benton is occasionally exposed along the arroyas, area marked B on map, and is often reached in well drilling. The same condition obtains to the east and northeast of Minneola. Each of the wells, numbers 1, 2 and 3 on map, reached the Benton, and 2 and 3 passed through it into the Dakota. At Mr. Hall's place, well number 4, three miles east of Wilburn, two wells were started at his house, each of which struck the Dakota at 60 feet, the Benton not reaching this far south. About 200 yards to the west of these, two other wells were drilled to a depth of over 90 feet without reaching the Dakota. Here the surface slopes gently to the west, and the Dakota is known to have a general rise to the west of about ten feet to the mile, so the Dakota should have been reached at about 55 feet. We therefore have the fault line located somewhere between these two groups of wells, all of which are in the southwest quarter, section 32, township 29 south, 25 west. About a half mile north of the C. R. I. & P. railroad and a little southeast of the Hall wells, another well—number 5—reached the Dakota. To the west of these wells, in the vicinity of Wilburn and Fowler, many wells are deep enough to have reached the Dakota did it exist in an undisturbed position where it should be, as best we can judge from its exposures farther northeast, and in the localities just given, where it is reached by the wells. Farther west both Benton and Dakota were reached by a well at Santa Fe, and the Dakota comes to the surface near the western line of the state.

The artesian valley is interesting in this connection. Many wells have been carried to a depth of 200 feet or more without

reaching the Dakota, and the one of Mr. Cooper, section 13, township 31 north, 28 west, reached a total depth of 250 feet and found no Dakota, which is at least 200 feet below where it should be found had it not been disturbed. The artesian water is found at depths varying from 50 to 250 feet, and under such varying conditions that it implies a filling in of the valley, producing even greater irregularities than is common to the Tertiary of adjoining areas.

Passing southward along Crooked Creek the first appearance of the "Red Beds" is on the east bank about three miles above the present location of Odee P. O.—not the place by a few miles as marked on the U. S. topographic sheets. They are again found on the east bank at Odee, and are exposed almost all the way below this point to the Cimarron, usually with the Tertiary capping the tops of the bluffs. Near Atwater, on the plain west of Crooked Creek, Mr. Ivers has recently drilled a well on section 3, township 34 south, 29 west, which was carried to the unusual depth of 288 feet without reaching the "Red Beds," while from their position a short distance east they should have been reached at about 100 feet. It is an important fact that no "Red Beds" can be found at or near the surface on the west side of the creek, while from here down to the Cimarron, and down the Cimarron to Englewood, they rise in bluffs along the east side to heights more than 100 feet. This condition obtains south of the state line, and after the western bluffs attain a considerable height. Passing on down the Cimarron, the "Red Beds" bluffs are markedly prominent on the north side with no traces of them on the south until a point in Beaver county, Oklahoma, is reached almost opposite the mouth of Col. Perry's irrigation canal—see map—when they appear on the south side and suddenly form as prominent bluffs as any on the north. By referring to the map it will be seen that this line is in range with the direction of Crooked Creek.

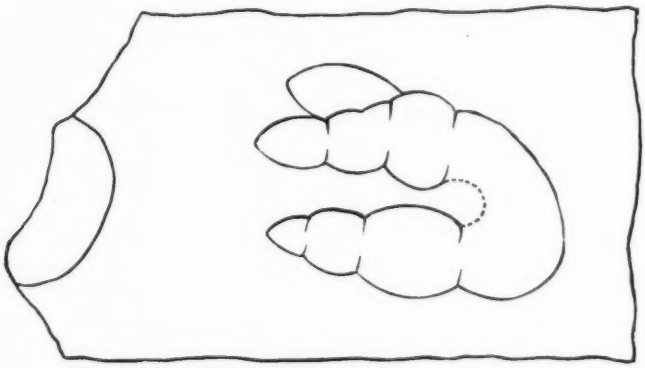
Summing the whole matter up, it would seem that the peculiar and apparently irregular conditions of physiography and geologic structure in the area under consideration can only be explained by assuming the existence of deformations principally due to a dislocation fault approximating in position the present location of Crooked Creek below Wilburn, a fault with the western side dropped at least about 200 feet.

Geological Department, University of Kansas,
Lawrence, Oct. 5th, 1896.

Art. LV.—*Amphibian Footprints from the Devonian;* by O. C. Marsh.

No evidence of vertebrate life higher than that of Fishes has hitherto been found in the Devonian formation. In the Carboniferous next above, however, many characteristic remains of Amphibians have long been known, proving that this form of vertebrate life was comparatively abundant at that period.

The Yale Museum has recently secured from the upper Devonian strata of western Pennsylvania, a specimen that shows one vertebrate footprint in fair preservation, and with it part of another of the same series. These impressions are of much interest, both on account of their geological age and the size and character of the footprints themselves. The one best preserved is nearly four inches in length, two and a quarter in width, and was apparently made by a left hind foot. On the inner side in front of the heel, a portion of the margin is split off, and this may have contained the imprint of another toe. The other footprint was a short distance in front, but only the posterior portion is now preserved in the present specimen. It is probably the imprint of the fore foot. The figure shown below represents these two impressions.



Outline of Devonian footprints (*Thinopus antiquus*, Marsh).
One-half natural size.

The specimen here figured was recently found in the town of Pleasant, one mile south of the Allegheny River, Warren County, Pennsylvania, by Dr. Charles E. Beecher, who presented it to the Yale Museum, and also furnished the present information in regard to its geological position.

The geological horizon is near the top of the Chemung, in the upper Devonian. In the same beds are ripple marks, mud cracks, and impressions of rain drops, indicating shallow

water and shore deposits. Land plants are found in the same general horizon. Marine mollusks also occur, and one characteristic form (*Nuculana*) is preserved in the footprint slab.

This specimen, although not important in itself, is worthy of record as indicating the existence of an air-breathing vertebrate, apparently amphibian, in the Devonian, and also as offering an incentive to further exploration in the same horizon.

Yale University, New Haven, Conn., October 16, 1896.

ART. LVI.—*The Geology of Block Island (Continued)*; by O. C. MARSH.

THE short article with the above title, in the last number of this Journal (pp. 295–298), was essentially a preliminary notice in the discussion of a much larger question relating to the presence or absence of the Jurassic formation on the Atlantic coast, a subject that I have been investigating for several years. The main object was to record my own observations at a few points, with the conclusions suggested, leaving a discussion of the whole subject for another occasion.

As my conclusions were so different from any that had been expressed by previous writers, I thought it best to present them based on my own investigations, rather than to attempt a discussion of the views of all others. To have cited the entire literature of the subject, extending over a century, would have taken the greater part of the limited space then at my command, and seemed hardly necessary.

Since my article was published, I have had further opportunity to follow out the investigation in several directions, and hope soon to place these results, also, on record. I may say here, however, that an examination of both the Raritan and Staten Island clay deposits has supplied two links in a chain of evidence, that I had not before known from personal observation. This chain now extends from the Potomac River to Martha's Vineyard, along the natural line of the Jurassic horizon, and indicates the Jurassic age of this series of strata beyond reasonable doubt.

Many and various opinions have been expressed as to the geological age of this series of strata, especially of the clays east of the Hudson River which are here under consideration.

The brilliant, variegated cliffs of Gay Head seem to have first attracted the attention of both mariners and geologists, and descriptions of their geological features began more than one hundred years ago. In 1786, Samuel West and William Baylies together explored Gay Head, and separately recorded what they saw, in vol. ii, Memoirs of the American Academy of Arts and Sciences, 1793. They discovered the bones of

whales, sharks' teeth, petrified shells, and fossil wood, and agreed that the cliffs were due to volcanic action, an opinion still maintained by the existing Gay Head Indians.

In 1824, John Finch, in discussing the "Tertiary Formations in America" (this Journal, vol. vii, pp. 31–43, 1825), stated his opinion that the Gay Head clays, as well as some on Long Island, and at Amboy, New Jersey, and still others farther south, were of the same age as the Alum Bay clays (Oligocene) on the Isle of Wight. E. Hitchcock, in the same year, and in the same volume of this Journal, pp. 240–248, regarded the Martha's Vineyard clays as the equivalents of the Plastic clay (Eocene) of Europe. Hitchcock, again in 1832, as state geologist, mapped and described this region as Tertiary, and in his report published in 1833 gave figures and descriptions of Gay Head fossils. The final report, 1841, contained a more complete description, and the Eocene age of the clays of Martha's Vineyard is still maintained. Lyell, in 1844 (Proc. Geol. Soc. London, vol. iv, and this Journal, vol. xlvi, pp. 318–320), made a study of Gay Head and other localities on the island, and regarded the cliffs as of Miocene age. E. Desor and E. C. Cabot, in 1849, announced that certain clays on Nantucket were Miocene, and the equivalents of those on Gay Head (Quart. Jour. Geol. Soc. London, vol. v, pp. 340–344). W. Stimpson, in 1860, pronounced the strata at Gay Head, Cretaceous (this Journal, vol. xxix, p. 145), but subsequently withdrew that opinion in favor of their Tertiary age.

In more recent times, also, this opinion still prevailed, and even the later age of Post-pliocene or Quaternary was, in 1885, assigned to the Gay Head clays by F. J. H. Merrill (Trans. N. Y. Acad. Sci., vol. iv, p. 79). Shaler, whose valuable memoirs on Martha's Vineyard and Nantucket (1888–'89) I quoted in my previous article, still regarded the basal clays of both islands as Tertiary or later. In another paper (Bull. Mus. Comp. Zool., vol. xvi, p. 89, 1889), he discussed the discovery of marine Cretaceous fossils in the drift of Martha's Vineyard. In a still later paper (Bull. Geol. Soc. America, vol. i, pp. 443–452, 1890), he considered the lower portion of Gay Head, Cretaceous, and the middle, Tertiary. He adds that A. F. Foerste observed, on Block Island, beds probably of the same age as the Tertiary at Gay Head.

A study of the fossil plants of Gay Head, in 1890, by David White, indicated that some of the clays of Martha's Vineyard were Mesozoic, and they were pronounced by him Cretaceous, and probably middle Cretaceous (this Journal, vol. xxxix, p. 99). To this important paper, I am indebted for various references. These researches were made under the direction of L. F. Ward, whose comprehensive work on the Potomac formation (U. S. Geol. Surv., 15th Ann. Rep., 1895) is invaluable to all interested in that horizon.

Block Island, owing probably to its diminutive size and isolated position, has attracted but little attention from geologists, although situated as it is between Long Island and Martha's Vineyard, it is an intermediate station of considerable importance. The first notice of its geological features is apparently that of C. T. Jackson, in 1840, in his report as state geologist of Rhode Island, pp. 111–120. He carefully described the Block Island clays, and considered them of Tertiary age, although he was unable to find in them any remains of marine shells.

The next notice of importance is by W. Upham, in 1879, who regarded nearly all the Block Island clays as of glacial origin. Some of them appeared to be older, but he makes no statement as to their age. After discussing Long Island, he sums up the effects of glacial action, as follows: —

"Excepting the pre-glacial deposits which have been mentioned, and a small area of gneiss and hornblende schist at Long Island City and Astoria, the whole of Long Island, Block Island, Martha's Vineyard, Nantucket, the Elizabeth Islands, and the peninsula of Cape Cod, consist of drift deposits which owe their accumulation, as has been here shown, to the action of the ice-sheet and its rivers in amassing them at its termination" (this Journal, vol. xviii, pp. 91, 92, and 207).

This general opinion has widely prevailed, and I referred to it in my previous article. Another paper on Block Island, which I have not seen, is by Merrill, 1895 (Trans. N. Y. Acad. Sci., vol. xv, pp. 16–19).

The literature relating to the geology of Long Island is quite extensive, but cannot be cited here. The basal clays of this island have been variously regarded as Glacial, Tertiary, and Cretaceous, but not older. The most important of the early descriptions is by Mather, in his Report on the Geology of the First District of New York, 1843. One of the later papers of special interest is by Merrill, On the Geology of Long Island, 1885 (Ann. N. Y. Acad. Sci., vol. iii, pp. 341–364).

Newberry, in 1874, pronounced the plants from Lloyd's Neck similar to those from the lower Cretaceous of the West (Proc. N. Y. Lyceum Nat. Hist., vol. ii, p. 127). This reference of the fossil plants of Long Island to the Cretaceous has since been followed by many authorities.

One of the latest writers on this subject is A. Hollick, who has kindly sent me, at my request, a number of his papers which I had not before seen.

The mutual relations of all the series of strata here considered, which I regard as Jurassic, I hope to discuss in the next number of this Journal.

Yale University, New Haven, Conn., October 21, 1896.

SCIENTIFIC INTELLIGENCE.

I. Chemistry and Physics.

1. *Lucium, a supposed new element.*—M. P. Barrière, in investigating monazite sand, has separated what he believes to be a new element; to this he has given the name *lucium*. Its chemical properties, compared with those of related elements, are stated to be as follows:

"The salts of cerium, lanthanum, and didymium form with sodium sulphate insoluble double salts; lucium does not. Thorium and zirconium form insoluble double salts with potassium sulphate; this is not the case with lucium. Yttrium, ytterbium, and erbium are not precipitable by sodium thiosulphate, whilst lucium chloride is precipitable. From glucinium lucium differs, as its salts are precipitable by oxalic acid.

According to the results obtained by Prof. Schützenberger, confirmed by those of Cleve, Fresenius, and Lecoq de Boisbaudran, lucium dissolves in sulphuric, nitric, or acetic acid, forming salts either white or slightly tinted with rose-colour. All its salts are soluble in water, forming limpid, colourless solutions.

The spectral rays of lucium are special, and only approximate slightly to those of erbium. Erbium oxide, on ignition, appears of a very pure rose-colour, and its nitrate is red. On the contrary, lucium oxide is white, slightly greyish, and its nitrate is white. The aqueous solutions of the erbium salts are red or rose-colour; those of lucium, even if containing 15 or 20 per cent of the salt, are almost colourless.

The atomic weight of lucium is calculated as = 104, whilst—

Thorium	= 233
Yttrium	= 89
Ytterbium	= 173
Scandium	= 44·5
Cerium	= 140
Lanthanum	= 156
Erbium	= 166
Zirconium	= 90
Samarium	= 150
Glucinium	= 9

Hence the authorities cited regard lucium as a new, distinct elementary body."—*Chem. News*, Sept. 25, 1896.

2. *On the occurrence of gallium in the clay-ironstone of the Cleveland district, Yorkshire.*—In the course of an investigation of flame spectra at high temperatures, W. N. Hartley and Hugh Ramage have examined the flames from the converters of the basic Bessemer process at Middlesbrough-on-Tees. A large number of photographs were taken, which are stated to have been remarkably fine in definition, and extending from the less refran-

gible limit of the red rays to the ultra-violet above wave-length 3240. The authors have identified all the lines and bands represented, and by this means have proved the presence of the rare element *gallium* in the Bessemer metal and in the roasted ore from which it was extracted. Careful analyses showed that the gallium was concentrated in the iron. The lines 4171·6 and 4032·7 (on Rowland's scale) were repeatedly observed in the spectrum of the Bessemer flame, again in that of the "mixer" metal and in the residue or precipitates separated from it, and finally in that of the residues obtained upon treatment of the roasted Cleveland ore itself.—*Proc. Roy. Soc.*, lx, 35.

3. *Flame temperatures.*—W. J. Waggener has made a detailed study of the Bunsen flame with the aid of thermo-couples of platinum and a 10-per-cent platinum-rhodium alloy. In most cases the wires of the couple were taken straight through the flame, with the junction nearest the center. The conductivity and the E.M.F. of the flame were found to be without influence upon the galvanometer currents. But in every case the wires had to be quickly removed from the flame after taking a reading, as their thermal E.M.F.'s suffered a gradual alteration in the flame. In the outer mantle of the flame the temperatures indicated by most of the thermo-couples ranged from 1500° to 1700° C., according to the height above the base of the flame. The hottest point was at a height of 2^{cm}; the total height of the flame being 10^{cm}. The coldest part of the flame, about 1400° C., was found near the top of the blue inner mantle. In all the observations, the conduction of heat along the wire reduced the temperature of the junction and vitiated the results. The hottest part of the flame, in the outer mantle, was 1724° C., as indicated by the thinnest of the wires ($0{\cdot}05^{mm}$ diameter). Taking the increase of temperature with the reduction of diameter, and plotting a curve, the latter is found to cut the axis of no thickness at a point corresponding to about 1770°, which may therefore be taken as very approximately the true value of the highest temperature of the Bunsen flame.—*Wied. Ann.*, lviii, 579; *Proc. Phys. Soc.*, xiv, 315.

4. *Liquefaction of Helium.*—K. Olszewski having been presented by Professor Ramsay with 140^{ccm} of helium, endeavored to liquefy it with the apparatus which he has used in his researches on oxygen and hydrogen.* The results were negative. Helium appears to be more permanent than hydrogen. The quantity of gas employed, however, was too small to afford definite conclusions. Olszewski believes that his experimental results show the single atom constitution of helium. The relation of this one atom constitution to the difficulty of liquefaction is even more marked in the case of helium than in that of argon. In consequence of its permanence of constitution helium affords a valuable means of determining temperatures beyond the boiling

*Further details in regard to these experiments were given in the October number, p. 301.

point of hydrogen. The hydrogen thermometer can not be used beyond —194°. The helium thermometer can afford useful service if it can be shown by further study to be reliable at the temperature —234·5°, which is the boiling point of hydrogen.—*Ann. der Physik und Chemie*, No. 9, 1896, pp. 184–92. J. T.

5. *Photometry of the ultra violet portion of the Solar Spectrum.*—HERMAN TH. SIMON refers to the various methods which have been employed in the less refrangible portion of the spectrum, and describes an apparatus which serves for the photometric study of the spectrum from the red to the ultra violet. The measurement of light intensity with the author's method reached an exactness of $\frac{1}{200}$: and the qualitative determination of the ultra violet absorption spectrum of a nitrate of potash solution gave a mean error of each determination of only 1·3 per cent.

The method consists of the use of a slotted revolving disc, by means of which the light of an arc lamp is suitably weakened, in order that comparison can be made with other sources of light, either by the eye method or by comparison of the intensity of photographic negatives.—*Ann. der Physik und Chemie*, No. 9, 1896, pp. 91–115. J. T.

6. *Electrical Indices of Refraction.*—P. DRUDE has continued his work on the electrical indices of refraction of water and aqueous solutions. The method consists in measuring the variation in length of electrical waves along wires before and after a definite length of the wires is immersed in the various solutions. The results were as follows:

For oscillations 4×10^8 per second, the square of the electrical index of refraction of water for 17° C. is $n^2 = 81·67$.

For oscillations $1·5\times10^8$ per second, $n^2 = 80·60$, for oscillations 8×10^8 $n^2 = 83·6$. Water shows normal dispersion within the limits of the rates of oscillation.

Between 0° and 26° changes in n^2 are proportional to the temperature.

With cane sugar solutions the electrical refractive indices are sensibly smaller than with pure water. The solutions show anomalous electric absorption and anomalous electric dispersion, and so much the more the higher the concentration. A 65-per cent solution absorbs the waves like an electrolytically conducting aqueous solution of the conductibility $k = 3\times10^{-7}$.—*Ann. der Physik und Chemie*, No. 9, 1896, pp. 17–62. J. T.

7. *Electrical Oscillations in a conducting sphere capable of polarization.*—RYDBERG, KAYSER and RUNGE have stated that there exist periodic relations between the spectral lines of different metals and the constitution of such metals. If N denotes the period of swing of lines belonging to the same series, $N = A - B\,n^{-2} - C\,n^{-4}$, in which A B C are constants,—n the position number of lines in the series; A B C have different values from series to series. In every spectrum there exists a principal series, with easily producible and easily reversible double lines, or in other words, two main series of simple lines which give oppor-

tunity for doublets. Only in the case of lithum exist simple lines. The breadth of the doublets, that is the difference between the powers of the position number n, increase as the fourth power of n. The number $n = 3$ in the case of sodium indicates the yellow D lines. With Li the red line, with K, Rb red double lines, and with Cs an ultra red double line, the higher values of $n = 4{\cdot}5$ etc. include the closely crowded together lines of the ultra violet portion of the spectrum. FRANZ KOLÁCEK has endeavored to find analogous series in the case of the electromagnetic swinging of a conducting sphere, which is capable of polarization, in a dielectrically polarizable ether. His mathematical analysis conducts him to series which are analogous to those treated by Kayser and Runge.—*Ann. der Physik und Chemie*, No. 6, 1896, pp. 271–310. J. T.

8. *A Magnetic Detector of Electrical Waves.*—E. RUTHERFORD states that the effect of Leyden jar discharges in partially demagnetizing them affords a simple and convenient method of detecting and comparing currents of great rapidity of alternation. The partial demagnetization of a collection of fine steel wires, insulated from each other, over which is wound a small solenoid in series with the receiving wires, was found to be a sensitive means of detecting electrical waves at long distances from the vibrator. A small but quite marked effect was obtained at a distance of half a mile from the vibrator.—*Nature*, July 9, 1896, p. 239. J. T.

9. *Discharge of an electrified body by means of the Tesla Spark.*—FREDERICK J. SMITH states that a high frequency spark between two blunt points one inch apart in air acts like the Röntgen rays in dispelling electric charges, of either sign.—*Nature*, July 30, p. 296. J. T.

10. *On the nature of the Röntgen rays ;* by J. J. THOMSON.*—The discovery at the end of last year by Prof. Röntgen of a new kind of radiation from a highly exhausted tube through which an electric discharge is passing, has aroused an amount of interest unprecedented in the history of physical science. The effects produced *inside* such a tube by the kathode rays, the bright phosphorescence of the glass, the shadows thrown by opaque objects, the deflection of the rays by a magnet, have, thanks to the researches of Crookes and Goldstein, long been familiar to us, but it is only recently that the remarkable effects which occur outside such a tube have been discovered. In 1893, Lenard, using a tube provided with a window made of a very thin plate of aluminium, found that a screen impregnated with a solution of a phosphorescent substance became luminous if placed outside the tube in the prolongation of the line from the kathode through the aluminium window. He also found that photographic plates placed outside the tube in this line were affected, and electrified bodies were discharged; he also obtained by these rays photographs through plates of aluminium or quartz. He found that

* From an address delivered before Section A of the British Association at the Liverpool meeting, *Nature*, vol. liv, p. 472 *et seq.*

the rays were affected by a magnet, and regarded them as the prolongations of the kathode rays. This discovery was at the end of last year followed by that of Röntgen, who found that the region round the discharge tube is traversed by rays which affect a photographic plate after passing through substances such as aluminium or cardboard, which are opaque to ordinary light; which pass from one substance to another, without any refraction, and with but little regular reflection; and which are not affected by a magnet. We may, I think, for the purposes of discussion, conveniently divide the rays occurring in or near a vacuum tube traversed by an electric current into three classes, without thereby implying that they are necessarily distinctly different in physical character. We have (1) the kathode rays inside the tube, which are deflected by a magnet; (2) the Lenard rays outside the tube, which are also deflected by a magnet; and (3) the Röntgen rays, which are not, as far as is known, deflected by a magnet. Two views are held as to the nature of the kathode rays; one view is, that they are particles of gas carrying charges of negative electricity, and moving with great velocities which they have acquired as they traveled through the intense electric field which exists in the neighborhood of the negative electrode. The phosphorescence of the glass is on this view produced by the impact of these rapidly moving charged particles, though whether it is produced by the mechanical violence of the impact, or whether it is due to an electro-magnetic impulse produced by the sudden reversal of the velocity of the negatively charged particle—whether, in fact, it is due to mechanical or electrical causes, is an open question. This view of the constitution of the kathode rays explains in a simple way the deflection of those rays in a magnetic field, and it has lately received strong confirmation from the results of an experiment made by Perrin. Perrin placed inside the exhausted tube a cylindrical metal vessel with a small hole in it, and connected this cylinder with the leaves of a gold-leaf electroscope. The kathode rays could, by means of a magnet, be guided so as either to pass into the cylinder through the aperture, or turned quite away from it. Perrin found that when the kathode-rays passed into the cylinder the gold leaf of the electroscope diverged, and had a negative charge, showing that the bundle of kathode rays enclosed by the cylinder had a charge of negative electricity. Crookes had many years ago exposed a disc connected with a gold-leaf electroscope to the bombardment of the kathode rays, and found that the disc received a slight *positive* charge; with this arrangement, however, the charged particles had to give up their charges to the disc if the gold leaves of the electroscope were to be affected, and we know that it is extremely difficult, if not impossible, to get electricity out of a charged gas merely by bringing the gas in contact with a metal. Lord Kelvin's electric strainers are an example of this. It is a feature of Perrin's experiment that since it acts by induction, the indications of the

electroscope are independent of the communication of the charges of electricity from the gas to the cylinder, and since the kathode rays fall on the inside of the cylinder, the electroscope would not be affected, even if there were such an effect as is produced when ultra-violet light falls upon the surface of an electro-negative metal when the metal acquires a positive charge. Since any such process cannot affect the total amount of electricity inside the cylinder, it will not affect the gold leaves of the electroscope; in fact, Perrin's experiments prove that the kathode rays carry a charge of negative electricity.

The other view held as to the constitution of the kathode rays is that they are waves in the ether. It would seem difficult to account for the result of Perrin's experiment on this view, and also I think very difficult to account for the magnetic deflection of the rays. Let us take the case of a uniform magnetic field: the experiments which have been made on the magnetic deflection of these rays seem to make it clear that in a magnetic field which is sensibly uniform, the path of these rays is curved; now if these rays were due to ether waves, the curvature of the path would show that the velocity of propagation of these waves varied from point to point of the path. That is, the velocity of propagation of these waves is not only affected by the magnetic field, it is affected differently at different parts of the field. But in a uniform field what is there to differentiate one part from another, so as to account for the variability of the velocity of wave propagation in such a field? The curvature of the path in a uniform field could not be accounted for by supposing that the velocity of this wave motion depended on the strength of the magnetic field, or that the magnetic field, by distorting the shape of the boundary of the negative dark space, changed the direction of the wave front, and so produced a deflection of the rays. The chief reason for supposing that the kathode rays are a species of wave motion is afforded by Lenard's discovery, that when the kathode rays in a vacuum tube fall on a thin aluminium window in the tube, rays having similar properties are observed on the side of the window outside the tube; this is readily explained on the hypothesis that the rays are a species of wave motion to which the window is partially transparent, while it is not very likely that particles of the gas in the tube could force their way through a piece of metal. This discovery of Lenard's does not, however, seem to me incompatible with the view that the kathode rays are due to negatively charged particles moving with high velocities. The space outside Lenard's tube must have been traversed by Röntgen rays; these would put the surrounding gas in a state in which a current would be readily started in the gas if any electromotive force acted upon it. Now, though the metal window in Lenard's experiments was connected with the earth, and would, therefore, screen off from the outside of the tube any effect arising from slow electrostatic changes in the tube, it does not follow that it would be able to screen off the

electrostatic effect of charged particles moving to and from the tube with very great rapidity. For in order to screen off electrostatic effects, there must be a definite distribution of electrification over the screen; changes in this distribution, however, take a finite time, which depends upon the dimensions of the screen and the electrical conductivity of the material of which it is made. If the electrical changes in the tube take place at above a certain rate, the distribution of electricity on the screen will not have time to adjust itself, and the screen will cease to shield off all electrostatic effects. Thus the very rapid electrical changes which would take place if rapidly moving charged bodies were striking against the window, might give rise to electromotive forces in the region outside the window, and produce convection currents in the gas which has been made a conductor by the Röntgen rays. The Lenard rays would thus be analogous in character to the kathode rays, both being convective currents of electricity. Though there are some points in the behavior of these Lenard rays which do not admit of a very ready explanation from this point of view, yet the difficulties in its way seem to me considerably less than that of supposing that a wave in the ether can change its velocity when moving from point to point in a uniform magnetic field.

I now pass on to the consideration of the Röntgen rays. We are not yet acquainted with any crucial experiment which shows unmistakably that these rays are waves of transverse vibration in the ether, or that they are waves of normal vibration, or indeed that they are vibrations at all. As a working hypothesis, however, it may be worth while considering the question whether there is any property known to be possessed by these rays which is not possessed by some form or other of light. The many forms of light have in the last few months received a noteworthy addition by the discovery of M. Becquerel of an invisible radiation, possessing many of the properties of the Röntgen rays, which is emitted by many fluorescent substances, and to an especially marked extent by the uranium salts. By means of this radiation, which, since it can be polarized, is unquestionably light, photographs through opaque substances similar to, though not so beautiful as, those obtained by means of Röntgen rays, can be taken, and, like the Röntgen rays, they cause an electrified body on which they shine to lose its charge, whether this be positive or negative.

The two respects in which the Röntgen rays differ from light is in the absence of refraction and perhaps of polarization. Let us consider the absence of refraction first. We know cases in which special rays of the spectrum pass from one substance to another without refraction; for example, Kundt showed that gold, silver, copper allow some rays to pass through them without bending, while other rays are bent in the wrong direction. Pflüger has lately found that the same is true for some of the aniline dyes when in a solid form. In addition to this, the theory

of dispersion of light shows that there will be no bending when the frequency of the vibration is very great. I have here a curve taken from a paper by Helmholtz, which shows the relation between the refractive index and the frequency of vibration for a substance whose molecules have a natural period of vibration, and one only; the frequency of this vibration is represented by OK in the diagram. The refractive index increases with the frequency of the light until the latter is equal to the frequency of the natural vibration of the substance; the refractive index then diminishes, becomes less than unity, and finally approaches unity, and is practically equal to it when the frequency of the light greatly exceeds that of the natural vibration of the molecule. Helmholtz's results are obtained on the supposition that a molecule of the refracting substance consists of a pair of oppositely electrified atoms, and that the specific inductive capacity of the medium consists of two parts, one due to the ether, the other to the setting of the molecules along the lines of electric force.

Starting from this supposition, we can easily see without mathematical analysis that the relation between the refractive index and the frequency must be of the kind indicated by the curve. Let us suppose that an electromotive force of given amplitude acts on this mixture of molecules and ether, and let us start with the frequency of the external electromotive force less than that of the free vibrations of the molecules: as the period of the force approaches that of the molecules, the effect of the force in pulling the molecules into line will increase; thus the specific inductive capacity, and therefore the refractive index increases with the frequency of the external force; the effect of the force on the orientation of the molecules will be greatest when the period of the force coincides with that of the molecules. As long as the frequency of the force is less than that of the molecules, the external field tends to make the molecules set so as to increase the specific inductive capacity of the mixture; as soon, however, as the frequency of the force exceeds that of the molecules, the molecules, if there are no viscous forces, will all topple over and point so as to make the part of the specific inductive capacity due to the molecules of opposite sign to that due to the ether. Thus, for frequencies greater than that of the molecules, the specific inductive capacity will be less than unity. When the frequency of the force only slightly exceeds that of the molecules, the effect of the external field on the molecules is very great, so that if there are a considerable number of molecules, the negative part of the specific inductive capacity due to the molecules may be greater than the positive part due to the ether, so that the specific inductive capacity of the mixture of molecules and ether would be negative; no waves of this period could then travel through the medium, they would be totally reflected from the surface.

As the frequency of the force gets greater and greater, its

effect in making the molecules set will get less and less, but the waves will continue to be totally reflected until the negative part of the specific inductive capacity due to the molecules is just equal to the positive part due to the ether. Here the refractive index of the mixture is zero. As the frequency of the force increases, its effect on the molecules gets less and less, so that the specific inductive capacity continually approaches that due to the ether alone, and practically coincides with it as soon as the frequency of the force is a considerable multiple of that of the molecules. In this case both the specific inductive capacity and the refractive index of the medium are the same as that of the ether, and there is consequently no refraction. Thus the absence of refraction, instead of being in contradiction to the Röntgen rays being a kind of light, is exactly what we should expect if the wave length of the light were exceedingly small.

The other objection to these rays being a kind of light is, that there is no very conclusive evidence of the existence of polarization. Numerous experiments have been made on the difference between the absorption of these rays by a pair of tourmaline plates when their axes are crossed or parallel. Many observers have failed to observe any difference at all between the absorption in the two cases. Prince Galitzine and M. de Karnojitsky, by a kind of cumulative method, have obtained photographs which seem to show that there is a slightly greater absorption when the axes are crossed than there is when the axes are parallel. There can, however, be no question that the effect, if it exists at all, is exceedingly small compared with the corresponding effect for visible light. Analogy, however, leads us to expect that to get polarization effects we must use, in the case of short waves, polarizers of a much finer structure than would be necessary for long ones. Thus a wire bird-cage will polarize long electrical waves, but will have no effect on visible light. Rubens and Du Bois made an instrument which would polarize the infra-red rays by winding very fine wires very close together on a framework; this arrangement, however, was too coarse to polarize visible light. Thus, though the structure of the tourmaline is fine enough to polarize the visible rays, it may be much too coarse to polarize the Röntgen rays if these have exceedingly small wave-lengths. As far as our knowledge of these rays extends, I think we may say that though there is no direct evidence that they are a kind of light, there are no properties of the rays which are not possessed by some variety of light.

It is clear that if the Röntgen rays are light rays, their wave-lengths are of an entirely different order to those of visible light. It is perhaps worth notice that on the electro-magnetic theory of light we might expect two different types of vibration, if we suppose that the atoms in the molecule of the vibrating substance carried electrical charges. One set of vibrations would be due to the oscillations of the bodies carrying the charges, the other set to the oscillation of the charges on these bodies. The wave-

length of the second set of vibrations would be commensurate with molecular dimensions: Can these vibrations be the Röntgen rays? If so, we should expect them to be damped with such rapidity as to resemble electrical impulses rather than sustained vibrations.

If we turn from the rays themselves to the effect they produce, we find that the rays alter the properties of the substances through which they are passing. This change is most apparent in the effects produced on the electrical properties of the substances. A gas, for example, while transmitting these rays is a conductor of electricity. It retains its conducting properties for some little time after the rays have ceased to pass through it, but Mr. Rutherford and I have lately found that the conductivity is destroyed if a current of electricity is sent through the Röntgenized gas. The gas in this state behaves in this respect like a very dilute solution of an electrolyte. Such a solution would cease to conduct after enough electricity had been sent through it to electrolyze all the molecules of the electrolyte. When a current is passing through a gas exposed to the rays, the current destroys and the rays produce the structure which gives conductivity to the gas; when things have reached a steady state the rate of destruction by the current must equal the rate of production by the rays. The current can thus not exceed a definite value, otherwise more of the conducting gas would be destroyed than is produced.

This explains the very characteristic feature that in the passage of electricity through gases exposed to Röntgen rays, the current, though at first proportional to the electromotive force, soon reaches a value where it is almost constant and independent of the electromotive force, and we get to a state when a tenfold increase in the electromotive force only increases the current by a few per cent. The conductivity under the Röntgen rays varies greatly from one gas to another; the halogens and their gaseous compounds, the compounds of sulphur, and mercury vapor, are among the best conductors. It is worthy of note that those gases which are the best conductors when exposed to the rays are either elements, or compounds of elements, which have in comparison with their valency very high refractive indices.

The conductivity conferred by the rays on a gas is not destroyed by a considerable rise in temperature; it is, for example, not destroyed if it be sucked through metal tubing raised to a red heat. The conductivity is, however, destroyed if the gas is made to bubble through water; it is also destroyed if the gas is forced through a plug of glass wool. This last effect seems to indicate that the structure which confers conductivity on the gas is of a very coarse kind, and we get confirmation of this from the fact that a very thin layer of gas exposed to the Röntgen rays does not conduct nearly so well as a thicker one. I think we have evidence from other sources that electrical conduction is a process that requires a considerable space—a space large enough to enclose a very large number of molecules.

Thus Koller found that the specific resistances of petroleum, turpentine, and distilled water, when determined from experiments made with very thin layers of these substances, was very much larger than when determined from experiments with thicker layers. Even in the case of metals there is evidence that the metal has to be of appreciable size if it is to conduct electricity. The theory of the scattering of light by small particles shows that, if we assume the truth of the electromagnetic theory of light, the effects should be different according as the small particles are insulators or conductors. When the small particles are non-conductors, theory and experiment concur in showing that the direction of complete polarization for the scattered light is at right angles to the direction of the incident light; while if the small particles are conductors, theory indicates that the direction of complete polarization makes an angle of 60° with the incident light. This result is not, however, confirmed by the experiments made by Prof. Threlfall on the scattering of light by very small particles of gold. He found that the gold scattered the light in just the same way as a non-conductor, giving complete polarization at right angles to the incident light. This would seem to indicate that those very finely divided metallic particles no longer acted as conductors. Thus there seems evidence that in the case of conduction through gases, through badly conducting liquids and through metals, electric conduction is a process which requires a very considerable space and aggregations of large numbers of molecules. I have not been able to find any direct experimental evidence as to whether the same is true for electrolytes. Experiments on the resistance of thin layers of electrolytes would be of considerable interest, as according to one widely-accepted view of electrolysis conduction through electrolytes, so far from being effected by aggregations of molecules, takes place by means of the ion, a structure simpler than that of the molecule, so that if this represents the process of electrolytic conduction, there would not seem room for the occurrence of an effect which occurs with every other kind of conduction.

In this building it is only fitting that some reference should be made to the question of the movement of the ether. You are all doubtless acquainted with the heroic attempts made by Prof. Lodge to set the ether in motion, and how successfully the ether resisted them. It seems to be conclusively proved that a solid body in motion does not set in motion the ether at an appreciable distance outside it; so that if the ether is disturbed at all in such a case, the disturbance is not comparable with that produced by a solid moving through an incompressible fluid, but must be more analogous to that which would be produced by the motion through the liquid of a body of very open structure, such as a piece of wire netting, where the motion of the fluid only extends to a distance comparable with the diameter of the wire, and not with that of the piece of netting. There is another class of phenomena relating to the movement of the ether which is, I

think, deserving of consideration, and that is the effect of a varying electro-magnetic field in setting the ether in motion. I do not remember to have seen it pointed out that the electro-magnetic theory of light implicitly assumes that the ether is not set in motion even when acted on by mechanical forces. On the electro-magnetic theory of light such forces do exist, and the equations used are only applicable when the ether is at rest. Consider, for example, the case of a plane electric wave traveling through the ether. We have parallel to the wave-front a varying electric polarization, which on the theory is equivalent to a current; at right-angles to this, and also in the wave-front, we have a magnetic force. Now, when a current flows through a medium in a magnetic field there is a force acting on the medium at right-angles to the plane, which is parallel both to the current and to the magnetic force; there will thus be a mechanical force acting on each unit volume of the ether when transmitting an electric wave, and since this force is at right-angles to the current and to the magnetic force, it will be in the direction in which the wave is propagated. In the electro-magnetic theory of light, however, we assume that this force does not set the ether in motion, as unless we made this assumption we should have to modify our equations, as the electro-magnetic equations are not the same in a moving field as in a field at rest. In fact, a complete discussion of the transmission of electro-magnetic disturbances requires a knowledge of the constitution of the ether which we do not possess. We now assume that the ether is not set in motion by an electro-magnetic wave. If we do not make this assumption, we must introduce into our equation quantities representing the components of the velocity of the ether, and unless we know the constitution of the ether, so as to be able to deduce these velocities from the forces acting on it, there will be in the equations of the electro-magnetic field more unknown quantities than we have equations to determine. It is, therefere, a very essential point in electro-magnetic theory to investigate whether or not there is any motion of the ether in a varying electro-magnetic field. We have at the Cavendish Laboratory, using Prof. Lodge's arrangement of interference fringes, made some experiments to see if we could detect any movement of the ether in the neighborhood of an electric vibrator, using the spark which starts the vibrations as the source of light. The movement of the ether, if it exists, will be oscillatory, and with an undamped vibrator the average velocity would be zero; we used, therefore, a heavily damped vibrator, with which the average velocity might be expected to be finite. The experiments are not complete, but so far the results are entirely negative. We also tried by the same method to see if we could detect any movement of the ether in the neighborhood of a vacuum-tube emitting Röntgen rays, but could not find any trace of such a movement. Prof. Threlfall, who independently tried the same experiment, has, I believe, arrived at the same conclusion.

Unless the ether is immovable under the mechanical forces in a varying electro-magnetic field, there are a multitude of phenomena awaiting discovery. If the ether does move, then the velocity of transmission of electrical vibrations, and therefore of light, will be affected by a steady magnetic field. Such a field, even if containing nothing but ether, will behave towards light like a crystal, and the velocity of propagation will depend upon the direction of the rays. A similar result would also hold in a steady electric field. We may hope that experiments on these and similar points may throw some light on the properties of that medium which is universal, which plays so large a part in our explanation of physical phenomena, and of which we know so little.

11. *Absolute hardness.*—F. AUERBACH shows that the method proposed by Hertz, and worked out by himself, of determining absolute hardness by the optical method, employing lenses and plates of the material in question, and finding what pressure of the one upon the other just brings about disintegration, is capable of great exactness and consistency. Special precautions must be observed to distinguish between the sources of error affecting brittle bodies and those affecting plastic ones. In the case of crystals it is necessary to define which face is operated upon. The best surface to choose is that of cleavage. The numbers obtained, expressed in kg. per sq. mm., show that Mohs's scale is far from giving a uniform succession of values. Talc figures at 5, but it is untrustworthy, and it should also be preceded by wax and graphite, and followed by gypsum, 14. Rock-salt is 20. Between this and calc-spar (92) there is a great gap, which might well be filled up by sylvine, glauberite, and galena. Fluorspar is 110. Then comes another gap, which should be filled up with scheelite, heaviest silicate flint-glass (170), and light flint-glass (210). Then comes apatite (237), followed closely by adularia (253), which might be succeeded by borosilicate crown glass (274). Quartz, topaz, and corundum figure at 308, 525, and 1150 respectively; and diamond is not as yet determined.— *Wied. Ann.*, lviii, 357; *Proc. Phys. Soc.*, xiv, 296.

12. *Determination of Freezing Points;* by J. A. HARKER. (Abstract from the Proc. Roy. Soc., lx, 154.)—Of recent years great improvements have been made in the construction of accurate thermometers. For their graduation and study, the position of the thread for at least two fixed temperatures must be known with certainty, and one of these is generally the freezing point. According to many observers, the methods at present in use for the determination of this point are unsatisfactory and cannot be relied on, even when considerable precautions are taken, to more than about 0·001° to 0·002°. The object of the present communication is to describe a method by which more consistent results can be obtained, and which is applicable to all kinds of thermometers.

The method adopted is to cool distilled water in a suitable

vessel, protected from radiation, to a temperature below 0°, to insert the thermometer, and then bring about the freezing of the water by dropping in a crystal of ice. The thermometer then rises, and finally attains a steady temperature, differing only very slightly from the true zero.

Within the space allotted to this abstract, it is not possible to describe in detail all the precautions to be adopted and the apparatus employed, and for these reference must be made to the original paper. The following brief outline may, however, be given.

The apparatus consists of two portions, the thermostat and the cooler. The former is a rectangular copper vessel, filled with some liquid, which can be cooled below 0° without solidifying.

Generally either refined petroleum or a strong solution of common salt is employed. This vessel communicates by means of two wide tubes with a system of coils in the cooler, through which the liquid can be pumped by a rotary stirrer. These coils are surrounded by a freezing mixture at about −8°, and by this means the circulating liquid can be cooled and maintained for some time at about −2°. The distilled water to be frozen is contained in a tube of about 300^{cc} capacity made of clear glass. This is first placed directly into the circulating liquid and cooled quickly to −0·5° or −0·7°. It is then transferred to a copper cylinder lined with polished metal, placed in the center of the thermostat, an annular space of about 1^{cm} being left between them. The thermometer whose zero is to be taken is then quickly fixed in position in a spring clamp, the bulb and a considerable length of the stem above the zero being immersed in the water. A crystal of ice is dropped in, and the temperature quickly rises to the freezing point.

For the details of the arrangement for the illumination of the divisions, and taking the readings through the mass of the liquid containing the ice crystals in suspension, reference must be made to the paper.

The amount of ice formed in the liquid varies of course with the undercooling. Experiments made with good mercurial thermometers showed that if ice be present in sufficient quantity, the final temperature attained by the mixture of ice and water is not influenced perceptibly by variation of the temperature of the circulating liquid within fairly wide limits. As, however, it is extremely doubtful whether the indications of any mercurial thermometer can be relied on beyond 0·001°, it seemed desirable to control this result by some other means.

A platinum thermometer and bridge were therefore designed, capable of indicating with certainty a change of 0·0001°, and a description of the whole arrangement employed to attain this degree of accuracy forms the second half of the paper. The resistances in the bridge were of manganin, whose temperature coefficient is only about $\frac{1}{20}$ that of the usual resistance alloys, and the plugs usually employed for short circuiting the coils were

replaced by copper bars and mercury contacts of specially low resistance. The thermometers employed were of about 10 ohms resistance, and were provided with the compensating leads, devised by Mr. Callendar. The maximum current which can be used in accurate measurements with these thermometers is about 0·02 ampère, and therefore the galvanometer employed required to be extremely sensitive. The instrument selected was a low resistance astatic one with vertical needle system of the type described by Weiss, and gives at the greatest sensibility at which the zero is steady one scale division for 1×10^{-10} ampère at 2500 scale divisions distance.

With this arrangement the influence of various conditions on the final temperature attained by the mixture of ice and water was studied. The results were found to be in close agreement with the theoretical deductions of Nernst, and it was found that with the right conditions, it was quite easy to keep the temperature in the freezing vessel constant, to within one or two ten-thousandths of a degree for an hour at a time.

The conclusion drawn from the previous experiments made with mercurial thermometers as to the small influence of changes in the external temperature, and in the temperature of the circulating liquid on that of the freezing vessel, was also confirmed, and it was found that in the final form of apparatus adopted, a change of two or three degrees in the temperature of the circulating liquid only caused the temperature of the mixture in the tube to alter by three or four ten-thousandths.

13. *Rœntgen Rays and Phenomena of the Anode and Cathode; principles, applications and theories*, by EDWARD P. THOMPSON. Concluding chapter by Prof. WILLIAM A. ANTHONY. 190 pp. 8vo. New York (D. Van Nostrand Company).—This volume contains a series of brief abstracts of the results and methods of many experimenters on the phenomena of the electric discharge, beginning with Faraday (1831) but including particularly the work of the past year upon the so-called X-rays of Röntgen. These notes are in numbered paragraphs arranged somewhat according to special subject under a series of chapters, with frequent cross references designed to call attention to the relation between them. Numerous illustrations are introduced including some forty-five half-tone reproductions of "sciagraphs" obtained by different experimenters. The general public will find this an interesting and convenient digest of the literature of the Röntgen rays.

14. *The Journal of Physical Chemistry.* Edited by WILDER D. BANCROFT and JOSEPH E. TREVOR. Vol. I, No. 1. 68 pp. Published at Cornell University, Ithaca, N. Y. October, 1896. —This new Journal comes forward to take a place not hitherto occupied among the scientific periodicals of the country. It will doubtless receive cordial support from all those interested in the department it represents. The first number contains articles by A. E. Taylor on irreversible cells (pp. 1–20); by F. Wald on

Chemistry and its laws (pp. 21–33); by W. D. Bancroft on Ternary Mixtures, II (pp. 34–50). The latter half of the number is occupied by book notices (pp. 51–58) and reviews of papers (pp. 59–68). The Journal is to be issued monthly, except July, August and September; price $2.50 per year.

II. Geology and Natural History.

1. *The geology of Somali-land.*—The study at the British Museum of fossils and rocks brought to England by members of the James Expedition, has given Dr. Gregory the evidence for interpreting the general features of the geology of Somali-land. In an article in the Geological Magazine (vol. iii, p. 293)* for July the following results are announced:

"The Somali-land sequence . . . . consists of the following:

1. Marine and subaërial recent deposits.
2. Neocomian limestones and cherts.
3. Duba limestone of uncertain age.
4. Bathonian limestones of Bihin.
5. Red and purple sandstones—unfossiliferous.
6. Archean series. (Gneisses penetrated by pegmatite dykes, etc.)

The discovery of the Bathonian fossils is of great interest. Bathonian rocks are known in Abyssinia from the work of Blanford, Ferret and Galinier, Aubry and Douvillé. They are also well known from the west coast of India in Cutch. They occur in northern Somali-land, exactly on the line joining these two localities. Mrs. Lort-Phillips' fossils are especially of value, as Rochebrune, on the basis of Révoil's collections from Somali-land, has disputed the accuracy of the determination of the Jurassic age of the Abyssinian limestones. The presence of Bathonian fossils in Somali-land, however, shows that, apart from the Abyssinian limestones, there are fossiliferous marine deposits of both Lower Jurassic and Neocomian age in this region of East Africa.

The occurrence of one species (*Parallelodon Egertonianus* Stoliczka) in Somali-land and in India helps to strengthen the idea of the former connection of the Bathonian rocks of India and Somali-land, which is suggested by the apparent extension of these rocks along an east and west line, from Cutch to Shoa. This is of interest, as it throws light on the origin of the interesting fauna and flora of the Golis Range. The report on the collection of plants made in the Golis Range, published in the Kew Bulletin of Miscellaneous Information (No. 105, September, 1895, pp. 211–30), shows that the flora of this district contains a very high proportion of endemic species (69 species out of 350 were new). This appears to be due to two reasons. In the first case, the Golis hills appear to contain limestones, which support a more varied flora than the soil formed by the weathering of the gneiss

* A note on the Geology of Somali-land, based on collections made by Mrs. E. Lort-Phillips, Miss Edith Cole, and Mr. G. P. V. Aylmer. By J. W. Gregory.

and schist. As travelers generally cross from the lowlands to the plateau by the Sheikh Pass, which has been cut down to the Archean series, they had previously missed this interesting flora.

In the second place, the high proportion of endemic species and the fauna and flora of these hills may be explained by their being inhabited by a group of species which entered the country from land which formerly extended to the east. In the discussion at the Geographical Society on Dr. Donaldson Smith's paper on his journey to Lake Rudolf, Dr. Bowdler Sharpe remarked that some of the Somali-land birds were allied to those of the Cape, and were unlike the representative species that live in the intervening parts of East Africa. It is most probable that the Jurassic rocks of Somali-land are part of a band which once extended eastward into the Indian Ocean, and may have been part of the hypothetical continent of Gondwana-land or Lemuria. This continent was probably separated from Equatorial East Africa, but was connected with the Cape. Thus it is quite possible that some species may have reached both the Cape and Somali-land without entering Equatorial Africa. Hence one of the constituents of the fauna and flora of Somali-land may be a remnant from those of the lost continent of Gondwana-land and Lemuria."

2. *Text-Book of Palæontology*, by KARL A. VON ZITTEL, translated and edited by CHARLES R. EASTMAN, Vol. I, Part I, pp. 1–352, 1896.—American students of geology and paleontology will take especial pleasure in the appearance of this admirable German treatise in English dress. It was originally intended to produce a literal translation into English of the "Grundzüge," immediately following its German edition, and Dr. Eastman, who was then a student at Munich, was selected by the author to conduct the translation. But as the work proceeded, and corrections and additions became numerous, specialists in England and America were consulted, and finally some of the sections were referred bodily to others for thorough adaptation to the needs of those who were expected to use them in the English language.

The Protozoa and Cœlenterata are translated with very slight modifications. A note on p. 82, however, calls attention to the important forthcoming work of Miss Ogilvie on the "*Structure and Classification of Corals*," which will materially modify the classification of the Madreporaria, hitherto constructed on the main lines of the Milnes-Edwards and Haimes system. The sections on the Crinoids and the Blastoids were revised under the direct supervision of Mr. Wachsmuth, and this part will be found to agree with the masterly monograph of Wachsmuth and Springer now being published by the Museum of Comparative Zoology on "*The Crinoidea Camerata of North America.*" The Cystoidea are substantially as in the Grundzüge. Special acknowledgments are expressed for assistance given by Mr. W. Percy Sladen in revising the parts on the Asterozoa and the Echinozoa, and particularly the chapter on Echinoidea, which is

made to accord with the new results published in Duncan's "*Revision of the genera and great groups of the Echinoidea.*"

The chapter on Bryozoa is entirely rewritten by Mr. E. O. Ulrich, whose numerous publications on this group have earned a well merited place in American paleontology. The *Monticulipora* find a place among the tabulate corals (p. 103) and again among the Bryozoa, but this reduplication is due to the fact that the earlier pages were already in type when the chapter on Bryozoa was written, and we are informed by the editor that in revised editions of Nicholson's work as well as of "*Grundzüge*" the Ulrich classification will be adopted.

The credit for having revised and practically rewritten the translation of the entire Brachiopod chapter belongs to Mr. Charles Schuchert. The classification adopted has been taken from his "*Synopsis of American Fossil Brachiopoda*," now in press, and it is in substantial accord with the recent monograph of Hall and Clarke, and with all the more advanced literature of American writers on the Brachiopoda.

The present part closes with the first few pages of the Mollusca, and it is to be hoped that the remaining parts will be rapidly brought out, since the paleontologist dealing with paleozoic fossils must have the whole of the invertebrates, at least, before him in the discussion of almost any full fauna, and such a work does not attain its best value as a text-book until it is complete.

American students will be particularly grateful to Professor Zittel, not only for supplying them with an English translation, but in allowing such liberal adjustment of the original work to be made by their own specialists. The work has thus become not only an English translation, but an Americanized edition of Zittel's standard work. And we have also to thank the editor for the skill with which he has rendered the German into excellent English while preserving the scientific accuracy of the author. H. S. W.

3. *Structural details in the Green Mountain region and in eastern New York;* by T. Nelson Dale. (Extract from XVIth Annual Report of the Survey, 1894–95. Part I, p. 543–570. U. S. Geological Survey, Washington, 1896.)—The author has here collected, mainly from the Taconic region, illustrations of inclined, overturned, transverse and unequal folding, false-bedding, obscuration of bedding by cleavage, differential cleavage, cleavage-banding, two and threefold cleavage, cleavage along fault lines, stretching, brecciation, and siliceous segregation, most of which are intended as fresh illustrations of well-known geological principles. One of them, however, "cleavage-banding" is not so familiar, and rather perplexing. At the end is an index to descriptions of related structural phenomena previously published by the author in other U. S. Geological Survey Reports which readers interested in this branch of geology may find useful. The paper has thirty-one diagrams, sketches and photographs.

4. *The Mineral Industry, its Statistics, Technology and Trade in the United States and other countries to the end of 1895.* Vol. IV. Edited by RICHARD P. ROTHWELL. 849 pp. 8vo. 1896. New York and London (The Scientific Publishing Company).—This fourth volume of the *Mineral Industry*, published under the auspices of the Engineering and Mining Journal, brings the subjects discussed down to the close of 1895. The editor-in-chief is Mr. Richard P. Rothwell, but he has had the assistance of a large corps of helpers in the different departments. The many who have used to advantage the earlier volumes of this series will remember that it gives not only a summary of the condition of each industry with respect to amount of material mined at different points, both in this country and abroad, but also a synopsis of the course of the prominent markets, as at New York and London; also in many cases an account is given of the treatment of ores. Special chapters discuss related topics of interest, as the evolution of the anthracite coal trade; labor, wages and accidents in mining; the depth to which it is plausible to think that mining operations may be carried in the future; the application of electricity to mining, etc.

5. *The Botanical Gazette. Editors, John M. Coulter, The University of Chicago, Ill., Charles R. Barnes, University of Wisconsin, J. C. Arthur, Purdue University; Associate Editors, George F. Atkinson, Cornell University, Volney M. Spalding, University of Michigan, Roland Thaxter, Harvard University, William Trelease, Missouri Botanical Garden.* CHICAGO, ILL. PUBLISHED BY THE UNIVERSITY OF CHICAGO.—It gives us great pleasure to note the substantial improvement by which this excellent journal is made to take an assured place in the front ranks of periodical scientific literature. It has been carried steadily forward by the energy and self-denial of its early projectors, under serious discouragements arising from slender pecuniary support and the lack of a permanent home. Happily, its founder and two of its early editors have adhered to it through days of trial, and they now have the justifiable satisfaction of seeing it accepted as an official publication of Chicago University, enlarged in scope, enlisting the services of four associate editors, and commanding the respect of botanists throughout the world. From the outset the editors have evinced good judgment in securing for the Gazette illustrations of high order and in insisting on good typographical execution. In the new volume, beginning with July of this year, the same severe taste is manifest, with the result of giving us a technical journal of which every American botanist may feel proud. G. L. G

6. *The Dualistic Theory of Descent.*—This is the name given by Sachs to a suggestive hypothesis concerning derivation, which he has presented in FLORA (*Marburg*) during recent numbers, the last of which bears date of June 3, in the issue for July 4. The style possesses the charm which has rendered all of the writings of Sachs agreeable reading and leads the reader often to give

his partial adherence to views which on subsequent study he cannot accept. Within the limits of space now at our command we can merely call attention to the attractive papers now referred to, and express the hope that the phylogenetic aphorisms may soon be placed before our readers in a convenient form. G. L. G.

III. Miscellaneous Scientific Intelligence.

1. *British Association for the Advancement of Science.*—The annual meeting of the British Association was held at Liverpool during the week beginning September 14th. The gathering was a notable one in various respects; as regards size it ranked among the largest, the attendance aggregating nearly 3200. Much interest was aroused by the inaugural address, delivered by the President, Sir Joseph Lister, upon the germ theory and antiseptic methods in surgery. Other important addresses were delivered before the several sections, as that by Prof. J. J. Thomson upon the Röntgen rays, reprinted in part (from Nature) in the present number. This subject also formed the theme of numerous papers in the physical section.

The next meeting is appointed for August, 1897, at Toronto, Canada, under the Presidency of Sir John Evans. This will be held simultaneously with the meeting of the American Association at Detroit, and arrangements have already been made for an exchange of courtesies between the two scientific bodies. The meeting for 1898 is to be held at Bristol, and that for 1899 at Dover, the latter in conjunction with the meeting of the French Association appointed for Boulogne on the opposite side of the British Channel.

2. *Report of the Sixth Meeting of the Australasian Association for the Advancement of Science*, held at Brisbane, Queensland, January, 1895. Editor, John Shirley. 875 pp. Sydney, 1896.—This volume, recently received, contains the record of the meeting of the Australasian Association at Brisbane, Queensland, in January, 1895. It includes the various Presidential addresses and also a considerable part of the long list of papers presented and grouped under the usual sections.

3. *Ostwald's Klassiker der Exacten Wissenschaften.* — The following are the titles of the most recent additions to Ostwald's valuable collection of scientific classics:

Nr. 76. Theorie der Doppelten Strahlenbrechung, abgeleitet aus den Gleichungen der Mechanik von F. E. Neumann (1832) 52 pp.

Nr 77. Ueber die Bildung und die Eigenschaften der Determinanten. (De formatione et proprietatibus Determinantium.) Von C. G. J. Jacobi (1841). 73 pp.

Nr. 78. Ueber die Functionaldeterminanten (De determinantibus functionalibus). Von C. G. J. Jacobi (1841). 72 pp

Nr. 79. Zwei Hydrodynamische Abhandlungen von H. Helmholtz. I. Ueber Wirbelbewegungen (1858). II, Ueber discontinuirliche Flüssigkeitsbewegungen (1868). 79 pp.

OBITUARY.

M. HIPPOLYTE FIZEAU, the French physicist, died recently at the age of seventy-seven. His name will be long remembered in connection with his determination of the velocity of light.

"Born in 1819, Fizeau was only thirty years of age when his paper, 'Sur une expérience relative à la vitesse de propagation de la lumière,' appeared in the Comptes Rendus. In this he put forward his plan of rotating a wheel having round its rim alternate teeth and spaces of equal width, so that these teeth and spaces should alternately intercept and allow to pass a beam of light from a source, and so adjusting the speed of rotation that the time occupied by the light in traveling from the wheel to a mirror and back again, should be equal to the time taken by the rim of the wheel to advance through a space equal to an integral number of times the width of a tooth or space. Curiously enough, the other experimental method of finding the velocity of light was described by Foucault in the very next volume of the Comptes Rendus. In some respects the latter method—that of the revolving mirror—was even more striking than that of Fizeau. It allowed the velocity of light to be determined within an ordinary room, and, besides, enabled the question as to whether light traveled more or less quickly through a more refractive medium to be decided by direct experiment.

Another experiment of capital importance with which the name of Fizeau will ever be honorably associated is that by which he determined the amount of drift of light-waves in a transparent medium in motion. According to a theory given by Fresnel, the velocity of drift of ether-waves in a medium moving with velocity u is $(1-1/\mu^2)u$, where μ is the index of refraction of the medium. This conclusion of Fresnel was verified more lately by the experiments of Airy and Hoek, which proved, in opposition to the statement of Klinkerfues, that no change in the constant of aberration is observed when the tube of the observing telescope is filled with water. But it was tested directly by Fizeau in the most simple and beautiful manner. Two tubes were arranged side by side, and water was forced at a considerable speed (as much as seven meters per second) along one tube and back by the other, while a beam of light was split into two parts, which were sent round the tubes, one with the stream, the other against the stream, and then brought together again and tested for interference produced by the virtual difference of path traversed, arising from the motion of the water. The result gave exactly the formula quoted above, and has been confirmed by very careful experiments made comparatively recently by Michelson and Morley."—*Nature*, Oct. 1.

SR. LUIGI PALMIERI died at Naples in the early half of September at the age of eighty-nine. He was director of the Observatory at Vesuvius and made important contributions to meteorology and seismology.

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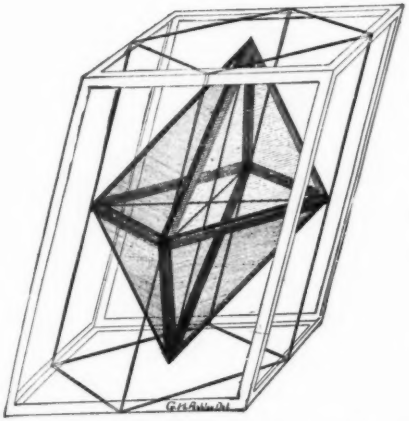

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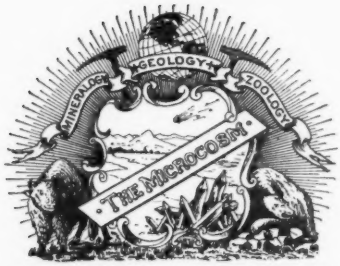

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(1) Described in this Journal Sept., 1895. (2) Ibid Nov., 1887. (3) Proc. Roch. Acad. Sci., Vol. 1. (4) This Journal Aug., 1888. (5) Ibid July, 1893. (6) Ibid June, 1894.

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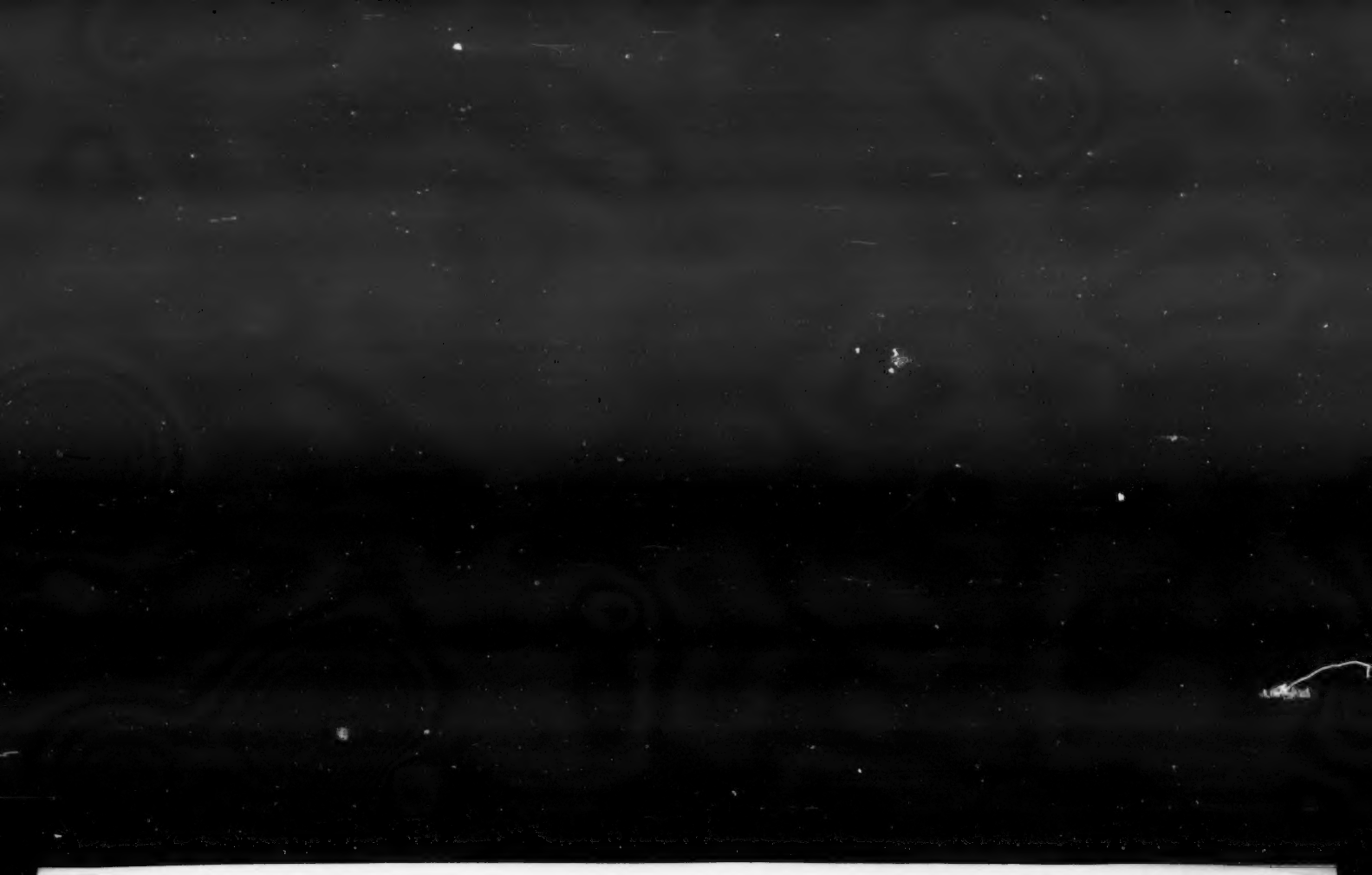
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